CORN PLANTS

HEIR USES AND WAYS OF LIFE

FREDERICK LEROY SARGENT

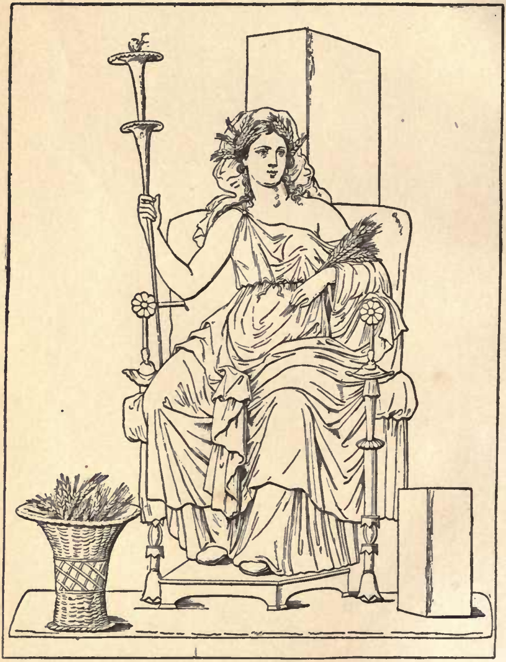

Fig. 1. Ceres, the Roman goddess of grains. Wall-painting from Pompeii.

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BY

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WITH NUMEROUS ILLUSTRATIONS

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PREFACE.

This little volume aims to present attractively to young people trustworthy information regarding a few of the most important plants in the world. It is believed that the book will be of value also to older readers who seek an elementary knowledge of the subject, and do not object to being addressed on such matters in simple language freed from unnecessary technicalities. Not that the unwise attempt has been made to avoid all technical expressions; they have been introduced, however, always with a sufficient indication of their meaning, and none are used which all readers are not likely to welcome as saving more trouble than they make.

Although intended for use in schools, this volume is not offered as a text-book, but rather as affording profitable reading supplementary to text-books, or as giving material for teachers' talks.

The main purpose is to enliven the study of plants by showing some of their most intimate relations with our daily lives. This purpose involves the casting of helpful side-lights upon a wide range of human concerns. In these pages not only are corn plants viewed sympathetically as living things, but the story is told of how man has been helped by them in different parts of the world, and at different periods of his advance from savagery. Studied in this way these familiar natural objects come to have an important educational value in helping the student to feel those vital connections between his various studies which should serve to knit them firmly together in his mind. In a word, the attempt has been made to show how the peculiarities of half a dozen supremely useful plants have affected the welfare of humanity, and have in turn been affected by human influence.

Only such features of these plants have been dealt with as may be readily observed with specimen in hand. Aided by the illustrations it should be possible for any one to recognize in the living or the dried plant all the parts referred to, and to repeat the simple experiments suggested. Every competent teacher must realize that no pictures or descriptions, however accurate, can well take the place of good specimens of the objects portrayed. The best service which this little book can render is to enhance the keen enjoyment which comes from careful and thoughtful examination of corn plants. If the reader desires to know these plants as they are, he must see them, handle them, and watch them at different periods of their life.

A large share of the figures were drawn by the author directly from nature. The others have been copied from well-known sources which are duly indicated. To the botanists of the Harvard Herbarium grateful acknowledgments are due for the use of books and specimens. To the schoolteachers whose

kindly criticisms have given the author much help and encouragement in his effort to meet an educational need, he would here tender his sincere thanks; and finally, he would also express his warmest gratitude to the other friends who have aided him most practically in the details of preparation.

CAMBRIDGE, March, 1899.

The silver coin reproduced on the cover and title-page is of the ancient Greek colony of Metapontum in Southern Italy, and dates from 330–314 B. C. On the obverse appears the head of Persephone, the corn maiden, or of her mother, Demeter, the goddess of agriculture. The hair is bound with corn. On the reverse of the coin are an ear of barley and a plough, symbolizing the great fertility of the territory of Metapontum.

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CORN PLANTS.

I. What Corn Plants are.

It is somewhat curious how differently the word "corn" is understood by different peoples. In the United States we generally mean by it simply maize or Indian corn; but the Scotch use it as meaning oats, and to most Englishmen an "ear of corn" suggests nothing but a head of wheat, while throughout the northern part of the European continent a "cornfield" is understood almost always as a field of rye.

If we turn to our Authorized Version of the Bible we find the word "corn" used in several interesting ways. It is said that Ruth coming to Bethlehem "in the beginning of the barley harvest" asked "to go into the field and glean ears of corn" (Ruth i. 22 and ii. 2). But it was "in the time of the wheat harvest" that Samson burned "the standing corn of the Philistines" by tying firebrands to the foxes' tails (Judges xv. 1, 5). The humane statute of Moses "Thou shalt not muzzle the ox when he treadeth out the corn" (Deuteronomy xxv. 4) undoubtedly applies to all the grain plants harvested by the Israelites. Finally, in the words of Jesus, "except a corn of wheat fall into the ground and die, it abideth alone" (John xii. 24), the meaning of corn is plainly *kernel.*

How did "corn" come to have these different meanings? The dictionary tells us that the word first meant simply a hard, edible seed, grain, or kernel,[1] and was applied especially to such kinds as were of most importance for food. From this it would be but a short step to speak of the plants which bore such kernels, as "corn plants" or "corn" in general. Then whichever of these plants was most familiar to a people naturally came to be known as "the corn" of that region, or simply as "corn," while those corn plants which were in less common use were distinguished by their separate names. Thus we account for the different ways in which "corn" has been understood by different people at different times. In this book we shall use the word as a general name to include wheat, barley, rye, oats, rice, and maize — the six plants which produce the principal breadstuffs of the world, and the most valuable of all vegetable foods.[2]

[1] An example of this use is found in the word "barleycorn," which means either a kernel of barley or a measure of length, three barleycorns being equal to one inch.

[2] The general name "corn" is applied also to several other plants which resemble more or less the six above named. Thus, there is the *Kaffir-* or *Guinea-corn*, otherwise known as *dhourra* or *Indian millet*. This is extensively used for food in Africa and Southern Asia. Then there are the *true millet*, and the *Italian millet*, which are somewhat similar plants that have been long cultivated in the Old World. In Central America a corn-like plant called *teosinte* is highly valued for food. *Quinoa*, a South-American plant very like our common pigweed, produces grain much used in the mountainous regions. These and also *buckwheat*, which is grown to a considerable extent in many countries, are sometimes included among corn plants: but all of them, and others which might be mentioned, are of so much less importance to us than are the six great corn plants named above, that we shall not need to consider them further in these pages.

II. The Importance of Corn Plants to Mankind.

Corn plants, as we know, are called also *cereals* or *cereal grains*. How they came to receive this name is a question which is of interest not only because the answer must lead us very far into the past, but also because it will help us to realize how important these plants have been to civilized people from the earliest times.

Like so many of our words this name is of Latin origin, and was used in nearly its present form by the ancient Romans over two thousand years ago. The people of those days, as we know, had many myths. These often meant a great deal to them, for it was only through such stories of gods and heroes that they felt able to account for the wonders of nature. Of all these ancient myths one of the most beautiful and significant was the following, which will aid us in understanding the origin of the name "cereal."

The Story of Ceres and Proserpine.

Ceres was the goddess of agriculture and especially watched over the growth of grains. (See Fig. 1.) Proserpine, her only daughter, was a girl of wonderful loveliness and the joy of her mother's heart. When the world was new they dwelt together upon the earth. The maiden loved flowers dearly and was never happier than when playing among them in the fields. One day she strayed off by herself to gather some rare blossoms which grew in a certain valley. There Pluto, the god of the underworld, chanced to see her, and so charmed was he by her exquisite beauty that he determined at once to carry her off, that she might always live with him and brighten the gloom of his realm below. As he caught up the frightened girl into his golden chariot, her flowers fell to the ground. So also did the girdle which she had worn. When night came and Proserpine did not return, Ceres was filled with fear least some harm had befallen her daughter. With torch in hand she searched far and wide. Dawn came and found the poor mother distracted with grief and still wandering with the lighted torch. No one whom she met could tell her where Proserpine had gone, though all were moved with pity. Day after day and night after night she searched, passing through many lands, till at last she came to a place in Greece called Eleusis. Here, utterly discouraged, she sat down to weep. Toward nightfall a poor man and his wife found the goddess, thus bowed with grief, and, thinking her to be a mortal, tried to comfort her. They offered her the hospitality of their home. They, too, were full of sorrow, for their only son, Triptolemus, was sick unto death. Touched by the tender kindness of these good people, Ceres went with them, and to their exceeding joy healed Triptolemus. Then revealing her true nature she promised some day to teach the lad what would make him honored by all mankind. She then continued her anxious search, yet with a lighter heart, for the hope had come again that she might soon find some trace of her daughter. It was not long before she came upon a bunch of withered flowers and the girdle which Proserpine had let fall from the chariot. Near by was a huge crack in the ground. Now Ceres felt sure that the earth had opened to swallow her child. Full of anger at the earth's ingratitude the goddess cursed the land, and brought drought and famine. Though every creature suffered, still even those who knew well what had happened dared not tell Ceres, for fear of Pluto's wrath. At last the nymph of a certain fountain which flowed from the underworld was so moved by all the misery which had come upon the earth, that she could hold the secret no longer. So, when Ceres came one day to the fountain, the nymph cried out to her, "O Goddess, blame not the land for what has befallen! I have seen thy daughter in the realms below. Pluto has made her his queen." On hearing this Ceres hastened to the throne of Jupiter, chief of the gods, and implored him to give command for Proserpine's release. This he agreed to do, provided the maiden had eaten no food while in the lower world: for so willed the Fates, whom even the gods obey. But alas! it was found that she had tasted some of the pulp of a pomegranate which the wily Pluto had given her, and in so doing had put six of the seeds into her mouth. She was doomed therefore to remain six months of every year with Pluto in the world below; but for the other half of the year she was permitted to live in the realm of sunshine with her mother, and each year Spring was to lead her forth. Pluto had been so kind to Proserpine that she had grown fond of him and did not feel at all sorry about the seeds. Ceres was content in that her daughter was so far restored to her. Bestowing once more her favor on the land she caused it to bring forth abundantly. She remembered, moreover, her promise to Triptolemus and taught him the use of the plough, the sowing of seed, and the raising of grain. These things, in his turn, he taught mankind, and thus through his teachings came the beginnings of agriculture.

As the reader has doubtless already discovered, we have in this charming myth little more than a poetic story of the corn plant, which, like Proserpine, passes a season in the earth, awaiting the gentle hand of Spring to lead it into the light of day. Also we have the thought that the beginnings of agriculture came with man's first knowledge of the growth of grain.

The Roman Cereal Festivals.

That such was the real meaning of the myth to the ancient Romans is shown by the way in which they celebrated their great agricultural festivals. These were held each year at springtime and harvest. From the twelfth to the nineteenth of April came a series of important ceremonies in memory of the return of Proserpine. Throughout the country the people marched in procession around their fields, imploring the favor of Ceres upon the growing grain. In the city the worshipers, all dressed in white, went to the temple of Ceres, bringing incense and honey, and cakes of wheat and barley as offerings to the goddess. On the last day of the festival elaborate games were held in her honor. The second festival coming in August was a feast of thanksgiving. At this the firstfruits of the grain harvest were brought as an offering to Ceres. The ceremony was performed by women alone, dressed as before in pure white. So sacred was this office considered that a fast of nine days was required as a preparation.

The gifts to Ceres, offered at these festivals, were called by the Romans *cerealia munera* (Ceres' gifts), or simply *cerealia.* We can now answer our question as to how corn plants came to be known as "cereals." Since by far the most important of the gifts to Ceres were from wheat and barley, it was very natural that these plants should come to have the name *cerealia* or *cereals* applied especially to them ; and when other similar grains came into use, it was equally natural that they should be included under the same general name. Thus it was that the word came finally to have the wide sense in which we use it to-day.

Other Corn Rites and their Meaning.

How came the Romans to have this story of Ceres and Proserpine? The fact is that they borrowed it from their neighbors, the Greeks. Long before the Romans began to hold their cereal festivals, the Greeks celebrated with even greater magnificence what were known as the "Eleusinian Mysteries." These were so called because the chief ceremonies took place at Eleusis, the home of Triptolemus, where, as the Greeks believed, this great benefactor of mankind had first established the worship of the goddess of grains. The celebration of these "Mysteries," which took place early in autumn, formed the great religious event of the year. It lasted many days, and the various ceremonies were arranged to commemorate in a striking manner the doings of the leading persons in the myth of the corn maiden. But most significant of all were the concluding rites, in which the worshipers were permitted to handle and taste the sacred symbols of the goddess, and finally amid profound silence beheld a living corn plant cut down by the priest.

In the Hebrew Scriptures we read of the Israelites, at the yearly festival of the Passover, preparing, at Moses' command, unleavened bread in memory of their flight from Egypt; and also as part of the same celebration, bringing the first sheaf of the harvest as an offering to Jehovah. After the harvest was gathered came the festival of Pentecost or Harvest Feast, when, amid great rejoicings and thanksgivings, loaves of leavened bread were brought before the Lord. "The whole ceremony," says a learned writer, "was the completion of that dedication of the harvest to God, the giver, . . . which was begun by the offering of the wave-sheaf at the Passover." [1]

Among the Assyrians and Babylonians who were akin to the Hebrews, and dwelt in the fertile valley of the Tigris and Euphrates, we find evidences of a similar appreciation of the value of corn plants. One of their ancient monuments recently discovered shows a great king in priestly robes offering for a sacrifice an ear of wheat. (Fig. 2.)

As wheat was valued by the peoples of Assyria and Babylonia, so has rice been held for ages in the highest estimation by the people of China. One interesting proof of this is a royal ceremony of seed-planting, believed to have been instituted by one of their emperors who reigned 2700 B. C. Every year for these many centuries the seeds of rice and of four other food plants have been sown with appropriate rites by members of the government. The rice is always planted by the emperor in token of its supreme importance.

We learn from accounts of early explorers in the New World that maize was similarly valued by that remarkable people, the Nahuas of ancient Mexico. This grain was extensively cultivated as the staple crop of the region, and in much the same way in which the Romans sacrificed to Ceres the firstfruits of their grain harvests, the Nahuas offered with elaborate

[1] See Exodus xxix. 23, 24.

FIG. 2. Assurnazirpal, king of Assyria (883–859 B. C.), as priest offering a kid and a head of wheat for a sacrifice. Bas-relief. (Layard.)

ceremony the firstfruits of their cornfields to Centoatl, their goddess of maize. The ancient Peruvians almost worshiped the maize plant as a divinity. At harvest time, as they returned home singing from the fields, the people reverently carried a large bundle of maize wrapped in rich garments. This they called by the name of their harvest deity, Perua. For three nights they continued the worship of Perua, imploring protection for the maize they had gathered.

When our forefathers came to this country they found the "Indian corn," as will be remembered, largely cultivated by the aborigines of North America. In fact it was to this fortunate circumstance that many of the colonists owed their lives; and we may well believe that if it had not been for the corn of the Indians, the brave attempts to establish colonies in the colder parts of the New World might have failed for lack of food. Hence in the celebration of our Thanksgiving Day, since this festival was founded by those who were thus sustained, it has been deemed particularly appropriate that especial prominence should be given to Indian corn among the grains which are used in church decoration and otherwise on that occasion.

From what has been said and from what is to follow, it will be seen that throughout the world there has been from earliest times the closest connection between the growing of grains and the progress of mankind — that, in a word, cereals and civilization have ever gone hand in hand. Moreover, it will appear that as nations have advanced in culture and importance, their dependence upon corn plants has been not less but greater. In this we may see the reason why among all peoples these plants which have yielded to them their daily bread have ever stood as a symbol and supreme example of the best gifts of the Giver of Life.

III. Corn Plants in the Field.

Why it is that corn plants play so important a part in our daily lives, and why certain of them are more highly valued than others, are questions which must be answered by referring to peculiarities of the plants themselves. We shall be helped, therefore, in trying to understand the deep connection between our lives and theirs, if we consider first the way in which they live.

How they Manage against Wind, Weight, and Wet.

It may be said in general of all these plants that they are never so much at home as when growing in broad, wind-swept fields. A special fitness for such life in the open is shown in every part of a corn plant and in its whole behavior. We may well credit those who tell us that in order to realize fully what corn plants are like when at their best, one should see them growing in the vast fields of our great North-western States.

Not long ago I heard of a little girl who had come East from a Western wheat farm. She had never seen the ocean, and when taken to get her first view of it she did not seem to be so much impressed as her friends expected she would be. After a while they asked her if she did n't like it. "Oh yes," she replied, "I like it very well because it has waves, but I like the waving wheat at home a great deal better." Those of us who have seen the ocean only may wonder at such a comparison, but it will not surprise us when we stop to think that not even the Atlantic can give a greater impression of immense extent than a grain field stretching out on every side as far as the eye can reach.

The very characteristic and beautiful wave effect, which every one has noticed in a field of grain as the leaves or ripening heads bow before the wind, is made possible by a remarkable arrangement of elastic material in the framework of the plant. If we examine one of the long, slender leaves, we find it to be strengthened by numerous springy threads extending from base to tip. They form a sort of skeleton for the leaf. In the larger leaves of corn plants, especially those of maize, we find, besides the many slender threads which run side by side throughout the length of the leaf, a bundle of threads of extra thickness and strength, running like a backbone through the middle of the blade. It is owing to these threads that the blade of a corn plant when at rest naturally takes a broad, graceful curve, like that shown in Figure 3. Yet the springs are so delicately elastic that they yield at the slightest breath of air, while the leaves are so formed as to allow a stronger wind to pass with only the least possible pull upon the stalk.

In the stalk we have the same sort of springy material formed into similar threads, but, instead of being in a flat row like those of the leaf-blade, they are arranged in the form of a tube. The tubular form gives much greater stiffness, and that is what the stem especially needs, since it has not only its own weight to support but also that of the leaves and, in course of time, the fruit.[1]

[1] We mean by *fruit* the seeds and whatever adjoining parts ripen in connection with them.

Fig. 3. Maize plant. T, tassel; S, stalk; L, leaf; E, E, E, ears; N, N, nodes; B, B, brace roots; R, earth roots; G, G, surface of ground. (Original.)

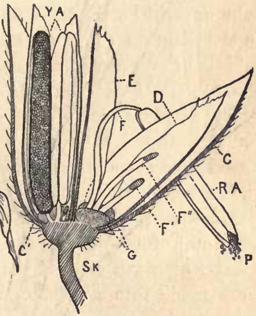

Fig. 4. Maize. A spikelet from the tassel cut lengthwise to show its two flowers, the one on the right fully open, the other not yet mature. Sk, stalklet; C, C′, outer bracts; D, E, inner bracts of the open flower; G, lodicules, which by swelling spread the bracts apart; F′, F″, filaments cut across; F, filament bearing ripe anther (R A) shedding pollen (P); Y A, young anthers, the left hand one cut to show the pollen. Enlarged. (Original.)

The great advantage derived from the tubular arrangement is well shown by the following simple experiment. Take a piece of writing paper, say eight inches long by three wide. Observe that when flat it has not stiffness enough to sustain even its own weight in an upright position. Now roll it lengthwise into a tube about three quarters of an inch in diameter, and to prevent its unrolling slide on to the tube three squares of paper having a hole of the same diameter as the tube cut from the centre. Place the tube upright on the table and arrange books as shown in the diagram (Fig. 5) at P, B and G, so that the middle of one end of the book B will rest squarely on the tube. If now on this support additional books (W) be placed carefully, one at a time, it will be found that the tube will hold up a weight likely to astonish any one who has never tested the strength of such a seemingly feeble column.

Moreover, builders have discovered that in making a column for support the tubular form gives far greater strength than if the same amount of material were made into a solid cylinder. Hence the use of tubes as far as possible in bicycle frames, which require the utmost strength attainable with a small weight of material. There is only this drawback, that when the tube is very long in comparison with its width there comes the danger of collapse or flattening and falling together of the sides. In the grain stalk this is avoided by means of solid joints[1] called *nodes*,

[1] As the word "joint" is liable to be misunderstood, since it may mean either the place of a partition or a portion extending from one partition to another, we shall avoid confusion by using the botanical terms *node* (from the Latin *nodus* meaning a knot) and *internode* (Latin *inter*, between).

which act as cross partitions dividing the whole stem into a series of tubes (the *internodes*) each of safe length. (Figs. 3, 12, 13, and 14 II.)

It should be noticed, also, that the need for stiffness is not the same in all parts of the stem, but increases towards the base; for, plainly, the weight to be upheld

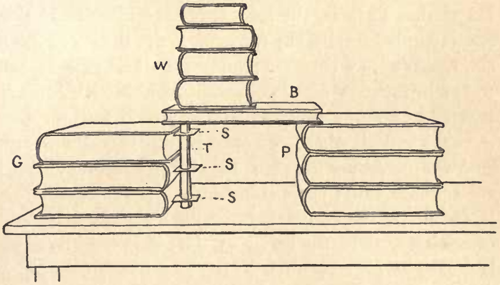

Fig. 5. Experiment with paper tube. T, paper tube; S, S, S, pieces of paper slipped over the tube to prevent unrolling; P, pile of books as high as tube; B, book, of which one end rests on P, while the other is supported by the tube; W, books added as weight; G, pile of books slightly lower than P, coming under B, to guard against fall of W. (Original.)

and the bending strain caused by wind become greater and greater in the lower parts. To provide this extra stiffness the distances between the nodes are less and less as the base is approached, while at the same time there is in the internodes some thickening of the wall.

As we pass upwards from the base of the stem not only does the need for stiffness become less but there is a steadily increasing need for as much springiness as possible. This is necessary in order that the upper parts may yield readily before the wind, and allow it to pass with least resistance, and hence with least strain upon the lower portions. We know that a slender rod is the best form to secure flexibility in every direction, just as a tube is the form of greatest stiffness for a given amount of material. As might be expected, therefore, we find the upper portion of grain stems increasingly slender and the cavity of each internode becoming much less in proportion to the wall. That is, the internodes are more and more rodlike, until finally the uppermost are nearly or quite solid. We see this particularly well shown in the upper branchlets of the oat stalk, where the springy material is made into wirelike supports well-nigh as delicate and elastic as the steel hairspring of a watch.

An apparent exception to the general rule that corn plants build their stems on the tubular principle is found in the stalk of Indian corn. Here, instead of a cavity, as in the straw of the other cereals, there is a core of pith through which run lengthwise a few slender threads. But we have only to remove a thin ring of the outer firm material of a maize stalk to find that the inner part, although forming the main bulk of the stem, is in reality very weak. Indeed, its value as an element of strength may be compared to a filling of sponge put into our paper tube. Hence we must conclude that whatever may be the use of this core of pith, the strength of a maize stalk is gained chiefly by its tubes of firm material, quite as truly as in the case of the other cereals.

These tubes of the maize stalk, it should also be said, are not always entirely cylindrical (as they are in the straw of other corn plants), but at several of the internodes are grooved or flattened on one side. Those of my readers who have ever made a "corn stalk fiddle" will remember that it was this peculiar flattening which rendered possible the manufacture of that rustic instrument. The part of the stalk chosen for the purpose always includes an internode which has one side flattened against an ear. Along the edges of this flattened part run woody threads of remarkable toughness, which provide the strings for the fiddle. With a sharp knife these threads are separated from the rest of the internode except at the ends where they join the nodes, and are then stretched over a "bridge" consisting of a cross slice cut from a neighboring internode. When played upon by a "bow" made from the upper and more slender part of the stalk, such a fiddle will give forth a perceptible if not always an agreeable tone.

In making this interesting toy one is led to observe certain facts which help to an understanding of the peculiar form of the maize stalk. Thus the fact that those internodes which are grooved have each an ear on the grooved side clearly indicates that this form helps to make room for the growth of the young ear. Moreover, any weakening which may result from the change of form is largely offset by the extra strength of the woody threads. It will also be noticed that usually the only internodes which are much flattened are those that come well above the base and hence are not so much subject to strain. The lower internodes, which have the greatest strain to bear, are, as we should expect, almost if not entirely cylindrical. Finally, it may be remarked that even the flattened internodes are really constructed on the tubular principle, although they are not quite so strong as if, with the same amount of material, they had been cylindrical in form.

We have seen that the tubular form of stem is the one which makes the strongest sort of a column that can be constructed with a limited amount of material. But we may also view it as the form requiring least material to be used in making a column which must have a given strength. When the tubular principle of stem construction is viewed in this way, it becomes plain that corn plants accomplish an important economy of their building material. This saving will in part account for the remarkable height which they attain during their short season of growth.

Another peculiarity of corn plants which greatly favors their rapid increase in height is the way in which new material is added at a number of separate places along the stem all at the same time. With most plants, as is well known, the stem becomes longer by the addition of new material entirely within a young and tender region at the tip. The way such a plant grows in length we may liken to the extension of a pocket telescope, when the sections beginning with the lowest are pulled out one at a time. If there were four sections to pull out and we took, let us say, one minute in pulling out each, then it would of course require four minutes to bring the telescope to its full length, in this way. Suppose, however, that instead of pulling out the sections one at a time, we could so manage that all of them would be extending at the same time and each as rapidly as before, then, plainly, the telescope would reach its full length in one minute. That is to say, in the second case, we should be pulling out the telescope four times as rapidly as in the first, or, in other words, as many times faster as the number of the sections extending at once. With corn plants, as we shall see, the extraordinarily rapid increase in length of stem is accomplished by having many sections extending at once, in much the same way as in our imaginary telescope.

Let us now see what we actually find in a growing grain stem. During the period of rapid elongation an examination of one of the older internodes even will show that while the upper portion has become so firm as to be incapable of further growth, the portion below is still rather tender, and near its base it is as full of sap and vigor as the tip of an ordinary shoot in springtime. Each internode by having its own special region of growth, which remains active for a comparatively long while, is therefore able to add to its length at the same time as the growing parts of the other internodes. Moreover we must not forget that in cereals, as well as in other plants, the stem grows also at the tip. This makes the extension of the separated growth regions of the older internodes in cornlike stems just so much clear gain for the plants which have this advantage. A large share of the life of field plants is an upward striving for light and air. The weeds which grow beside our cereal grains are for the most part easily beaten in this race, for they have not learned the secret which makes corn plants supreme. It would be hard to find among self-supporting plants a more rapid grower than maize, for example, which sometimes during its few months of growth reaches a height of nearly twenty feet.

Thus far we have been considering the stem as if it were the only part concerned in maintaining an upright position against the pulls of weight and wind. In any fair distribution of credit, however, the leaves must come in for a large share. The earliest green of the infant plant, which makes its way to the surface of the ground, is *leaf*, and until the appearance of a "tassel" or "head" at the top of the elongated stalk, a leaf-blade always forms the uppermost part of the plant. At first the whole leaf is rolled into a tube. As it grows, the upper part unrolls into a long flat blade. This blade bending outward exposes the rolled blade of a younger leaf. This younger leaf may in turn inclose a succession of still younger leaves, which will in time come out, but until they are ready to appear, each of them is infolded by the leaf next older than itself. Unlike the blade, the lower part of each leaf even when full grown does not unroll, but remains as a tubular sheath tightly wrapped about the stem. It thus reinforces the internode in the best possible way, especially toward the base where the younger growth makes support and protection most necessary.

By this admirable arrangement of tube within tube, each of the growing parts is given all the protection it needs, but no more than is good for it at any time. The youngest and tenderest leaves are the most protected. As they grow older and are better able to protect themselves, they are permitted more and more to do so, and at the same time they become of increasing importance as guards to the younger growth within. For the baby leaves, a tube forms the snuggest sort of a cradle. Moreover, the tubular form also enables the leaf to do stem's work, and this in two ways: first, in the blade, secondly, in the sheath. The blade, so long as it remains unrolled, grows, as we have seen, with remarkable rapidity, straight upwards in advance of the stem. The sheath, by retaining permanently its tubular form, continues not only to protect but also to give firm support to the lower end of the internode, which it infolds. In military language, it may be said that the blade forms the vanguard, while the sheath serves as the rearguard of the column.

Besides the mechanical support which a sheath provides and the protection it affords as a covering, there is yet another advantage gained by most corn plants from having the lower part of their leaves in the form of a cylindrical tube surrounding the stem. It will generally be found that the sheath, although firmly fixed at its lower end, revolves more or less freely in its upper part around the stem. This amount of play in the parts, as a trial readily shows, permits the blade to swing horizontally through nearly half a circle without bringing to bear on the stem more than a very slight twisting strain. The importance of this additional provision for lessening even the small resistance offered to the wind by these delicately responsive, pennon-like leaves will be apparent when we remember to what severe tests such field plants must often be subjected.

In maize there is still another provision for lessening the strain of the wind-tossed leaves on the stem. As the blade elongates, the parts toward the edge grow much more than the middle portion. Hence, the margin is thrown into the ample folds which give such a beautiful wavy effect to the leaf. (See Fig. 3.) At the base of the blade, on each side of the "backbone" or "midrib," are folds of especial prominence. (F, Figs. 6 and 7.) When the wind blows, say on the left side of a blade, the folds on that side permit the elastic midrib to bend readily away from the wind to a considerable extent before the edge is taut. Meanwhile, the other half of the blade, on the right of the midrib, is being folded into more of a ruffle; or it may be that the blade avoids the full force of the wind by a spiral twist which is made particularly easy on account of the ample edges. In any event the prominent folds at the base of the blade permit the midrib to bend at that point almost as if hinged. Thus in these largest of corn leaves, even though the sheath be immovable, a very wide swing away from the wind is made possible by simple means.

It is generally found to be true in mechanics that wherever special delicacy of action is required the danger of getting out of order is correspondingly increased. So it is with the revolving mechanism of the sheath. Since the successful operation of this depends upon the easy sliding of an outer tube upon an inner, danger arises from the possibility of rain getting in between the tubes and carrying along particles of dust or agencies of decay. Not only would this interfere more or less with the free swing of the leaf, but the accumulation of such particles, together with the moisture, might seriously injure both the stem and the sheath. Even in maize, where the sheath is immovable, such accumulations would be dangerous. To avoid all this is doubtless the purpose of that special outgrowth of the leaf at the junction of blade and sheath shown in Figure 15, R. This outgrowth, which we may call the *rain guard*, is generally pressed close to the stem, and along its line of union with the blade there is formed a broad channel to right and left. Whatever water may flow along the blade toward the stem is by this means carried around the rain guard to the opposite side, and there falls down over the sheath to the next rain guard below. Here the stream is similarly led

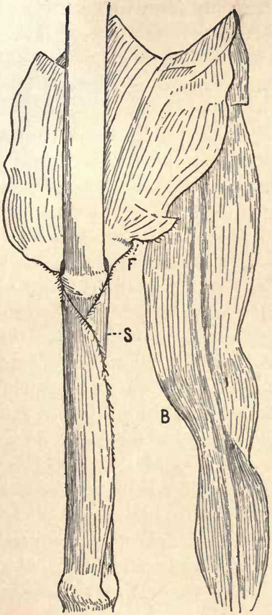

Fig. 6. Maize, leaf at rest. B, blade; S, sheath; F, a region of special fullness. (Original.)

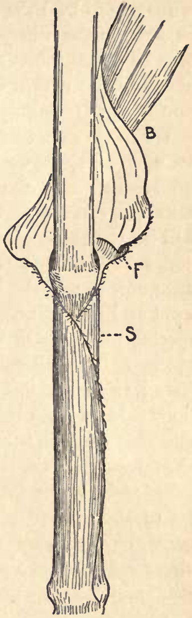

Fig. 7. The same, with the blade (B) blown to the right and thereby twisted, and a deep fold made at F, thus relieving the sheath (S) and the stalk of strain. (Original.)

around the stem once more, and downward, and so on till it reaches the roots. Thus, these several parts coöperate to lead the water away from where it would be harmful to where it is of greatest use. All this may be readily observed by watching a growing grain plant during a shower, or by imitating the effect of rain by a watering-pot.

When we were considering the strains coming upon an upright stem, we found that these must steadily increase towards the base, and thus become greater near the surface of the earth. This extra strain, as will be remembered, is met by having the lower internodes both thicker and shorter than the others. We have now to add the interesting fact that the forces of wind and weight are still further resisted by certain special roots which grow out from nodes near the ground. These *brace roots*, as they are called, extend on all sides obliquely downwards into the soil, and thus help to keep the stem upright in much the same way that shrouds support the mast of a vessel. As we should expect, the best examples of such roots are afforded by maize (Fig. 3), for this is by far the tallest of the corn plants, and most needs the extra support. The brace roots of maize are of especial interest also, from the fact that they often become remarkably stiff, and thus serve as props as well as shroudlike stays.

Were it not that corn plants have such effective means of resisting or avoiding the constant pushes and pulls upon every part, they could not accomplish their remarkable growth in the fields. Under all ordinary circumstances these brave plants manage to hold their own in a way that must win our admiration. But a moment's thought will show that however strong the lower parts may be and however widely spreading the brace roots, their strength is of little account unless the soil affords a firm anchorage. Hence, if a violent rainstorm soften the ground or perhaps wash away so much of the earth as to uncover the upper roots, then nothing can save these plants from being blown over flat upon the ground. To any one not familiar with the ways of corn plants, a field of grain overthrown seems hopelessly ruined. Yet the farmer knows better. Experience tells him that usually a few hours after such a storm has cleared away nearly every stalk will be found standing up as straight as ever. In reality to have been blown down was perhaps the best thing that could have happened to the plants under the circumstances, for if the lower parts had not given way they might have been seriously injured.

How is this fortunate recovery accomplished? Again the leaf sheath comes to the rescue. In order to understand just what has taken place, we need to examine with special care the parts near one of the lower nodes. In the oat, for example (Fig. 14 I.), on the outside of the stalk a swollen ring is to be seen (R) which at first sight might be taken for a part of the stem at the place of a partition. When, however, we cut through the whole lengthwise, as in Figure 14 II., the ring is found to be situated entirely above the partition, and to constitute in fact the base of the sheath. Even after the sheath is fully grown and has become stiffened as a support for the internode, this ring still retains its original sappy condition. Hence, the base of the sheath is ready at any time to grow again in case of need. It does grow, and in a peculiar manner, whenever the parts are placed in an unnatural position. So long as the axis points upwards the power of growth is not awakened; but let it point for a while in any other direction and the *undermost* part of the ring is stimulated to elongate.

This one-sided growth produces a bend in the stalk where the ring comes. The stem at this point, following the same curve as the sheath ring, causes the parts above to come gradually into an upright position. That is to say, the stalk rises as if by a self-acting hinge. Figure 14 III. shows part of an oat stalk which has become erect in this way. All corn plants, at least when their stalks are growing vigorously, have much the same power of recovery from the effects of violent storms. With maize, however, there is this difference, that instead of having a sheath ring play the most important part in bending the stalk, it depends in this matter mainly upon its stout lower internodes. These retain for a considerable time the same power of curving in case of need as displayed by a sheath ring.

Defenses against Drought.

Rainstorms, for all their violence, are not so hard a trial for field plants as drought. It has been estimated that wheat, under ordinarily favorable conditions, absorbs from the earth, and transpires, or breathes out through its foliage each day, an amount of water about equal to the weight of the plant. In an acre of wheat, during the course of the growing season, this would mean a loss of two hundred and fifty tons. Long continuance of dry wind and hot sun, by promoting loss of moisture from the foliage, would increase very much the amount thus withdrawn each day. At the same time, the supply of rain hav-

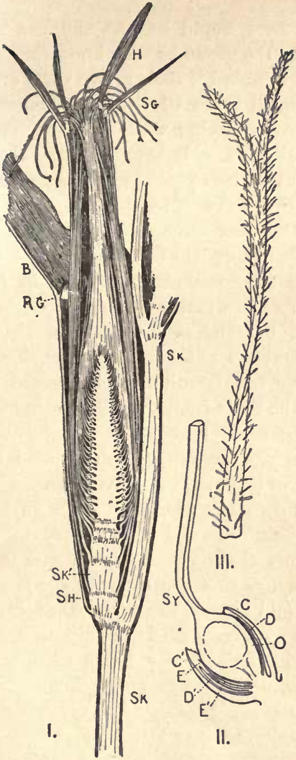

FIG. 8. Maize. I. A young ear cut through the middle lengthwise. SK, SK, the main stalk; SK′, the branch stalk which bears the ear; SH, sheath of the leaf infolding the whole ear; R G, rain guard; B, blade of the same leaf; H, husks; SG, stigmas ("silk") protruding beyond the husks.

II. A single spikelet of the ear, showing the bracts (C, C′, D, E, D′, E′) and the ovary (O) and lower part of the style (SY) of the single pistil. Enlarged.

III. Upper part of stigma, showing the delicate hairs that cover it. Enlarged. (Original.)

ing ceased, there would be less and less moisture to draw from in the ground. We know that the growth of plants is retarded if their active parts are deprived of even a small share of the large amount of water they ordinarily contain; while if the amount be much decreased they die. It thus appears that drought offers a most serious problem to plants of the field. There are two ways open to them for meeting the difficulty; they may extend their roots as far as possible into the deeper and moister layers of the soil, or they may in some way check the loss of water from their leaves. Corn plants do both.

The depth to which the roots of cereals will sometimes penetrate is not a little remarkable. No true idea of their full length may be gained by simply pulling up the roots from the soil, for they are so slender as to be easily broken far above the tip. The most satisfactory way is that described in the following account of observations carried on by a German botanist: "An excavation was made in the field to the depth of six feet, and a stream of water was directed against the vertical wall of soil until it was washed away, so that the roots of the plant growing in it were laid bare. The roots thus exposed in a field of rye . . . presented the appearance of a mat or felt of white fibres, to a depth of about four feet from the surface of the ground. The roots of winter wheat[1] he observed at a depth of seven feet, in a light subsoil, forty-seven days after sowing."[2] Such deep

[1] The name "winter wheat" is applied to those sorts which are sown in the fall, live over the winter, and ripen the following season. "Spring or summer wheat" is planted in the spring, and harvested before cold weather.

[2] Johnson's *How Crops Grow.*

penetration of the parts through which absorption takes place cannot fail to give to these plants a great advantage in times of drought.

Yet even the reserve supply of water in the lower layers of the soil would soon become exhausted if transpiration from the leaves went on as freely as under ordinary circumstances. This deep-lying water is the plant's last resource. Hence the special need for stringent economy of this reserve, by checking as much as possible all needless transpiration. We know that the loss of moisture from any part depends largely upon the extent of surface exposed to the surrounding air. A comparison of wheat plants from dry and from moist localities has shown that leaves of the former are narrower than those of the latter, of the same length, thus giving a helpful reduction of leaf surface in the drier localities. Perhaps a similar comparison of other corn plants from like localities might show similar difference in the leaves. It is not possible, however, for corn plants to have their leaf-blades much narrower than they generally are, without at the same time losing much of the benefit which comes from good exposure to sunlight.

What these plants need above all for safety and success in the field is some means of changing the form of their leaf-blades at different times. Only thus can a corn plant avoid the dangers of over-drying at one time, and yet at another time be able to take full advantage of the sunshine. Fortunately just such a ready adjustment to varying conditions is made possible by the easy change from the expanded to the tubular form of blade. It will be remembered that the leaf-blades in all cereals, so long as they are young and so in special danger of wilting from too rapid transpiration, retain the tubular form, and thus expose only a small portion of their surface to the drying action of the air. Yet even after they have become full grown and flat, the blades seem never to forget how well the earlier form had served their needs; for whenever it becomes necessary to check waste of moisture, the blade assumes once more as nearly as possible the form it had when young. That is to say, the edges roll inwards so as to cover the upper surface, and in some instances overlap in order to reduce still more the amount of surface exposed. In the ample leaves of maize not only do parts of the edge roll inwards, but the two halves of the blade fold together as if hinged at the midrib. Among farmers this "curling of the corn" is recognized as one of the most significant signs of drought.

Much the same tubular rolling of the leaves may be seen also in pasture grasses under similar circumstances or when the plants are being dried for hay. In all cases, when there is again sufficient moisture, the blade becomes flat as before. This power of resuming the expanded form promptly on the return of favorable conditions is, as we have seen, scarcely less important than the power of "curling." We know that the great work of food-making, which is what leaves are chiefly for, can be done to best advantage only when the blade is provided with plenty of moisture and spread out to receive the rays of the sun.

Food-making and Growth.

Food-making is the main purpose of the plant during what we may call the youthful period of its existence. To this end all the parts coöperate from the beginning. Some of the parts help by getting the necessary raw materials from the earth and air. Other parts serve by bringing these materials together in the foliage. Here the green parts use the power of sunlight to make over these crude substances into food in a way that only green plants can do. Finally there are other parts which carry off most of this precious product, in the form of a nutritious sap, to those portions of the plant which are actively engaged in building new structures or at least in doing other work than food-making. It is true that much of the inner workings of these various parts we can only guess at, for the plant is like a factory with the discouraging sign "no admittance." Yet even such general results of the work as may be seen from the outside are enough to show us that the whole is run on a singularly perfect system. There is no hiding the fact that so long as the plant is young there is a rapid growth of the organs which are especially concerned in making food, namely, the roots, stems, and leaves. We find, also, that the plant makes provision, as early as possible, for avoiding or repairing injury to those organs from wind, rain, or drought. Thus we may see that our self-building food-factory is governed by advanced business methods. From the start, the policy pursued is to devote at once as much as possible of the product of manufacture to building additions to the establishment and to insuring its future safety. It is as if there were a wise and enterprising manager in charge of its affairs.

The same spirit of enterprise which leads these plants to take fullest advantage of their opportunities appears also in the establishment of what we may call "branch factories." That is to say, under favorable circumstances, extra stalks are developed as outgrowths from near the base of the main stem. (See Figures 12 and 13.) These additional stalks are called "tillers." Each may grow into a leafy grain-bearing shoot like that from which it sprang. Each, moreover, sends out its own set of roots which enable it very soon to obtain for itself the necessary materials from the soil without depending upon the supply absorbed by the main roots. So complete is the independence thus secured that even if the connection with the main stem should happen to be severed the new branch can live on vigorously as a separate plant forming tillers of its own. This habit of tillering is especially well shown in wheat, oats, and rye, which not uncommonly produce as many as twenty stalks or more from one.

At the Botanic Garden in Cambridge, England, an experimenter who was curious to see how far this power might be taken advantage of to increase the yield from a single seed made the following trial. A kernel of common red wheat sown in June was found in August to have produced a plant so well tillered that it could be divided into eighteen separate plants. These being transplanted to give room for further development were found in the autumn to have branched so freely as to permit dividing them again into sixty-seven plants. After resting over the winter they resumed their vigorous growth in the spring, and tillered so well that a third division gave five hundred plants. These being transplanted were allowed to remain undisturbed until harvest, when it was found that some had produced over one hundred grain-bearing branches. Altogether, there were 21,109 heads yielding forty-seven pounds, seven ounces, of clear corn, or about 576,840 kernels as the product of a

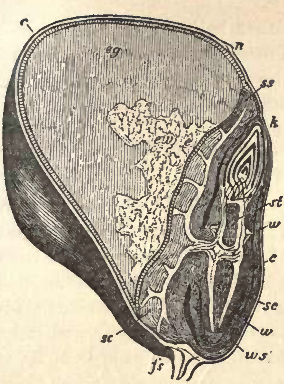

FIG. 9. Maize, a ripe kernel cut lengthwise through the germ. *c*, *c*, the outer layer or "hull"; *n*, the base of the style; *fs*, stalklet; *eg*, hard, yellowish part of seed food; *ew*, whiter portion of seed food; *sc*, *sc*, scutellum of the germ; *ss*, its point; *e*, its skin; *k*, the leaves of the germ packed closely in a bud; *st*, stem-part of the germ; *w* (below), the main root protected by a special covering or root sheath (*ws*); *w* (above), secondary root. Enlarged about 6 diameters. (Sachs.)

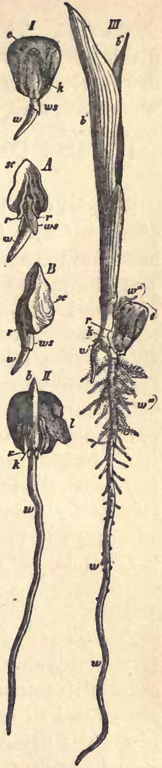

FIG. 10. Maize, kernels sprouting.

I. Kernel seen from the germ side. The main root (*w*) has just broken through the root sheath (*ws*). *k* shows where the young leaves and stem are still incased, and *e*, the part of the kernel where the food is stored. *A*, the germ removed, showing in front view the scutellum (*sc*) broken through, and the margins of the rift (*r*, *r*) spread apart. *B*, the same in side view.

II. The same as I, further advanced, showing, besides the more elongated root, the leaf cylinder (*b*) protruded beyond the covering (*l*), which it has pushed aside.

III. The same, still further advanced; side view. *b′*, *b″*, young leaves; *w′*, *w″*, *w‴*, secondary roots. Natural size. (Sachs.)

single seed. The gardener believed that if he had divided the plants once more in the spring (as he had done successfully in a previous experiment) the yield would have been increased fourfold.

IV. How Corn Plants provide for their Offspring.

So far as we have yet considered the life of corn plants, we have found them devoting their energies mainly to the making of food. The only use we have seen the plant make of this food is the building of additional food-making parts. Of course such increase of facilities for food-making cannot go on indefinitely, even though the tiller-branches become separated as independent plants. Sooner or later every individual plant must die. Hence the necessity for providing some means of starting new plants like itself. In corn plants the life of the kind is continued from generation to generation by means of seeds containing the beginnings of offspring. To produce such offspring and provide for their welfare becomes thus the final duty of the plant.

Seed-making.

Just as soon as its food-making arrangements are in good running order, the plant begins to devote a share of its surplus to the formation of new parts especially fitted to bring the seeds to perfection. These new parts develop more and more rapidly as the season advances, and so consume a larger and larger share of food, until finally, as we shall see, they take up about all the plant can make.

The parts which are especially concerned in perfecting the seeds present some interesting differences from the parts we have already examined. This we should expect, in view of the very different kind of service they have to render. We shall find, also, that they show some significant resemblances to those other parts, as if old forms had been, in a way, made over for new uses. Before we can well understand how the new parts serve their purpose we must carefully examine their peculiarities.

The Floral Parts.

If we examine a corn plant soon after the last leaf has appeared, there will be seen peeping out from its protecting folds a crowded cluster of numerous, small, delicate parts which, upon further growth, are found to be grouped into clusters of clusters. (Figures 12, 13, and 16.) This compound cluster constitutes what botanists call the *inflorescence* or floral portion of the plant, although it must be admitted that the flowers which it includes are very different in appearance from what are ordinarily so called. They agree with other flowers, however, in producing seeds. When this is accomplished, the inflorescence becomes the "head" or "ear" of grain. All the different corn plants agree in having the inflorescence borne at the top of the stalk as a termination to its growth.

Perhaps the most striking difference among grain plants is that which distinguishes the floral clusters of maize from all the others. As will be seen from Figures 12, 20, 23, 25, and 28, wheat, rye, barley, oats, and rice, have in each case but one sort of inflorescence, while maize (Fig. 3) has the two sorts ordinarily known as the "tassel" (T) and the "ear" (E). Moreover, the ears of maize appear as outgrowths from the side of the corn stalk, and this may seem to contradict the statement made above that the flower clusters of cereals always terminate the stalk. In this respect, however, these ears do not really differ from the terminal clusters borne by the tiller-stalks of this and other grains. If we cut down through an ear, as shown in Figure 8, we find that it is borne on the end of a stalk which is essentially like that of a tiller except that the ear-branch arises further up on the main stem and is shorter. Yet for all that, the number of internodes is about the same as in the main stalk.

One marked result of the way in which the stalk of a maize ear is shortened appears in the crowding of its leaves. Along with this goes a change in form which fits them for serving as husks to protect the tender parts within. It will be remembered that so long as the whole branch is tender, and thus in need of protection, it is completely covered by a leaf sheath belonging to the main stem. As the husks elongate, their upper parts emerge from the sheath and the outermost husks spread their blades on either side. In comparison with the leaves of the main stem these outer husk leaves are seen to have a smaller blade and rain guard, but as large a sheath. If now we compare with these outer husks the ones which they inclose, we find that both blade and rain guard become smaller and smaller as we proceed inward until finally we find nothing but pale, papery sheaths with no trace of blade or rain guard whatever. This gradual series of forms helps us to see that even the innermost husks, although so unleaflike in appearance, are really leaves. Moreover it is plain that since they are destined to remain entirely covered by the outer husks, these inner wrappers could make no use of either blade, rain guard, or the green coloring-matter of foliage. Hence there is no occasion for their being more leaflike than they are.

Leaving the other parts of the maize ear to be considered presently, let us now see what may be found in the flower clusters of the other cereals. We will begin with the floral parts of the oat (Figs. 16 and 17) as affording a good standard with which to compare the others. As already observed, the upper part of the main stalk is continued into the inflorescence, where it gives off several branches which bear the little clusters or *spikelets*. (B, Fig. 16.) The spikelets consist of a few parchment-like, sheathing organs (suggesting miniature husks) inclosing tender parts within. In fact it is chiefly in size that these little husks differ from the large ones of maize.

FIG. 11. Coyote corn, from Moro Leon, Mexico. An ear (natural size) with husks partly removed. The rachis or cob, when ripe, breaks readily into separate sections. (Drawn by the author from a specimen in the Herbarium of Harvard University.)

The husks of both must be looked upon as leaves of the flower cluster which differ from foliage leaves mainly in such particulars as fit them for the special service they have to perform. Leaves which are thus peculiarly developed in connection with a flower cluster are called *bracts*. The outermost bracts of the oat (C, Figs. 16 and 17), like the inner husks of maize, consist wholly of what corresponds to a leaf sheath. Commonly one or more of the inner bracts of the oat (D) resemble the outer ones of maize in having also a part corresponding to a leaf-blade which here takes the form of a slender projection (B, Fig. 17). This delicate outgrowth is called an *awn*. It is the development of such awns that gives us the "bearded" varieties of grain. In the oat, as will be seen, the awn stands out from the sheath at an angle much as a blade does. The sheath, moreover, is prolonged beyond the base of the awn, thus taking the place of a rain guard. We can hardly suppose, however, that this part of the oat bract is of much use in keeping out the rain.

When the plant is in bloom the bracts spread sufficiently to allow certain parts of the flowers they inclose to push out into view. (*B*, Fig. 16.) From each flower appear three little double sacks, the *anthers*, each borne on a slender thread, the *filament;* and two small feathery affairs called the *stigmas*. If we cut such a spikelet in half from the stalk up, as shown in Fig. 17, the innermost floral parts may be seen also. In the centre of the flower we find a rounded body, the *ovary* (Ov), which is a thin-walled case containing a tiny egglike structure, the *ovule* (Ol), that ripens into a seed. Each *stigma* (Sg) is connected with the ovary by a short stalk known as the *style* (Sy). Of these there are two to an ovary, as shown in *J*, Fig. 16: styles, stigmas, and ovary taken together form the *pistil* of the flower. Outside of this come the *filaments* (F, F′, Fig. 17) each bearing an *anther* (R A, R A′), from which when mature there may be shaken out through special openings innumerable yellow, dustlike particles called *pollen* (P). A filament with its anther make up a *stamen.* At the base of the flower is a pair of minute scales, the *lodicules* (G, Figs. 16 and 17), which are of use in pushing apart the bracts so as to expose the anthers and stigmas when the proper time arrives. All these floral parts are shown at an earlier stage of their development in the younger unopened flower Y F, Fig. 17.

There remains to be mentioned only one more portion of the oat spikelet. This is a pair of very small bracts (R F, Fig. 17) borne at the tip of the little rachis (R′). If we separate these tiny bracts there is found to be no flower within. We may regard them as indicating the place where a flower might have been expected but where none is developed.

A comparison of the inflorescences of the other cereals (Figs. 4, 8, 21, 23, 27, and 30) with the flowering portion of the oat will show that in spite of more or less striking differences of detail the general make-up is very much the same in all. That is to say, all have the same floral parts inclosed in bracts which may be readily recognized as such, although differing often considerably in size and form.

The reader may find it of interest to notice the following peculiarities which serve to distinguish the different kinds of corn plants when in blossom. Attention has already been called to the fact that maize has two sorts of inflorescence, the tassel and the ear, while in each of the other cereals there is only one sort of inflorescence. Of these latter, oats (Figs. 12, 13 and 16) and rice (Figs. 20 and 21) have their spikelets borne on rather long slender stalks, forming thus a loose open cluster; while rye (Figs. 23 and 24, *B*), wheat (Figs. 25–27), and barley (Figs. 28–30), have their spikelets very short-stalked and crowded, thus forming a compact spike or "head." Rice differs from oats in having, instead of several flowers within each spikelet, only a single flower which is like those of the oat except that it has six stamens, and has the awns when present borne on the very tip of the bract. (See Fig. 22.)

In rye, wheat, and barley, the awns when present grow like those of rice, from the tip of the bract, and being close together give the beautiful "bearded" appearance to the spikes of these grains. There results also from this crowding of the spikelets the curious flattened and zigzag form of the *rachis* or "backbone" of the spike shown at R, Fig. 27. Rye and wheat agree in having a single spikelet produced at each node of the rachis (Figs. 24, *B*, and 27, A), and in that particular they differ from barley, which has three spikelets at a node. (Fig. 30, B^3.) Rye has two flowers in each spikelet. Wheat has several flowers in each spikelet except a few of the lower ones, which are very small and flowerless. (See Figs. 25 and 26.) Barley has a single flower in each well-developed spikelet (see Fig. 30, B, B^1), but of such spikelets there may be only one or two in each group of three; in that case the other spikelets are flowerless and appear in rows from top to bottom of the spike. (Fig. 29.) Some kinds of barley have part of their flowers containing stamens but no pistil.

All the flowers of the maize tassel are like those of the barley just mentioned, in having stamens alone. (Fig. 4.) The ear of Indian corn is an enormously developed spike bearing a large number of spikelets, in each of which a single pistil is produced, but no stamens. (Fig. 8, I. II.) The pistil differs from those of the other cereals chiefly in having an exceedingly elongated style and stigma (SG) which form the "silk" of the ear. The bracts belonging to these hidden flowers of the maize ear are very delicate (II. C, C′, D, E, D′, E′,), and form the thin papery chaff which remains attached to the cob when the kernels are removed.

From what has been said of the flower clusters of the various cereals, it will be seen that however much the parts differ in minor details of structure and arrangement, they are all built upon essentially the same plan, although there is more or less modification according to need. This fundamental plan may be expressed in a general way as follows: the flowers consist typically of three stamens and a single pistil, although sometimes the number of stamens is doubled, and in other cases, either stamens or pistil, or both, may be wanting. Around these floral organs are protective bracts or inflorescence leaves, which may be more or less unleaflike in form, but which are like the other leaves of the plant in being arranged in two ranks on opposite sides of the stem which bears them. In having their flower clusters constructed in this way corn plants resemble the familiar wild grasses of pasture and meadow. Indeed, most of the features of structure we have described as belonging to cereals, and much of what we have still to consider, are found also in these other plants. Botanists recognize the closeness of this resemblance by including cereals among the members of the "grass family." This is as much as to say that the cereals are grasses which have come to be cultivated especially for their edible grains, much as "herd's grass" has come to be raised for its herbage.

The Beginning of the Seed.

Our study of the floral organs of corn plants has now prepared us for considering the question as to how these parts act together for the perfecting of seeds. If we ask why it is that so many parts are developed for this purpose, and why they are so strangely complicated in structure, the answer is that all this elaborate preparation contributes to the welfare of the plant's offspring. It is now known to be a great benefit for offspring to have when possible two parents, so that advantageous characteristics inherited from each may be combined. This key enables the botanist of to-day to unlock some of Nature's secrets which have baffled mankind for ages.

We have seen that an ovary contains an ovule ready to grow into a seed. It does grow provided some pollen from a plant of the same sort falls upon the stigma; otherwise no seed is developed. Hence, if a farmer should go through his maize field and cut off all the tassels as soon as they appeared, he would find the ears at harvest time sadly lacking in kernels. How it is that pollen resting upon the stigma is enabled to coöperate with the ovule in such a wonderful way would require many pages to explain. For our present purpose it is sufficient to know that a single pollen grain so placed does bring about in some way the development of the ovule into seed, and that the seed so produced is capable of becoming a plant which will inherit peculiarities not only from the ovule-bearing parent, but from the pollen-bearing one as well. It may happen that the pollen affecting the ovule was produced by the same individual plant that bears the ovule. In that case we have what is known as *close-pollination.* When the pollen of one individual is carried to the stigma of another we have *cross-pollination.*

Careful experiments have shown that, at least in the long run, the offspring resulting from cross-pollination are in many ways better plants than those produced through close-pollination. It is mainly for the purpose of securing to the offspring the important benefits of cross-pollination, or, as we said before, the advantage of having two parents, that corn plants develop such elaborate floral arrangements. For the accomplishment of this purpose, as we shall now proceed to show, they take advantage of the carrying power of the wind, thus making a servant of what was before an enemy.

Indian corn affords a particularly fine example of cross-pollination through the agency of the wind. The stamens held high in the air extend their anthers on slender threads well beyond the bracts. When fairly out, each pollen-sack, as shown in Figure 4, opens by a little hole at one side of the lower end. The arrangement is such that the closely packed dustlike pollen is held in readiness to be shaken out in small quantities by every passing breeze. At the same time, the particles are not so likely to fall in still air as if the opening were at the very bottom. If the pollen did fall directly down, it would either be wasted or else reach the stigmas of the same plant, and so effect close-pollination. Once confided to a current of air the pollen will be wafted sideways for a greater or less distance according to the strength of the current, until finally, having meanwhile sunk a few feet below the former level, some of the pollen grains may be blown against the long silky stigmas protruding above the husks of a young maize ear perhaps rods away. The pollen-grains would then become entangled among the slender hairs which cover these stigmas (see III. Fig. 8), and cross-pollination would be accomplished.

It has been admitted that the pollen of a maize plant may sometimes fall in still air upon its own stigmas. But there are two reasons for believing that this scarcely ever happens. In the first place, as we have seen, the anthers are so constructed that a breeze is generally required to shake out the pollen, and a breeze will carry the pollen away. In the second place, we find that, as a rule, the stigmas of the plant are not in readiness to receive pollen until after its own anthers have been emptied. Close-pollination is thus as unlikely to occur, as it is likely that cross-pollination will be secured.

Of course not all the pollen from a maize plant can be expected to find its way to maize stigmas in just the right condition to receive it. On the contrary a very large share must inevitably be lost. To make up for this a correspondingly large amount of pollen is produced. According to a careful estimate an average maize plant has seventy-two hundred stamens, containing about eighteen millions of pollen-grains. Since about two thousand ovules are reckoned to a plant, this would give nine thousand pollen-grains to an ovule. When it is remembered that a single grain falling upon a stigma is sufficient to insure the ripening of the ovule, we see that a very generous margin for mishaps has been allowed.

The provisions made for pollination in wild oat-grass (Fig. 31) are very like what are found in most grasses, and are of interest for comparison with those of cereals. The stigmas of a given flower cluster may or may not be protruded while anthers of the same cluster are shedding their pollen. In either case, however, there is a good chance that cross-pollination will be accomplished throughout most of the cluster, and that in one way or another all the stigmas will receive pollen even though it will be partly from the same plant. Such plants go on the principle that while cross-pollination is worth making a good deal of effort to obtain, it may sometimes prove impossible (as in the absence of neighboring plants of the same kind), and then close-pollination is much better than no pollination at all.

Fig. 12. Oat plant, showing general appearance after several tillers have formed. (Baillon.)

Among such grasses as the cereals, where innumerable individuals commonly grow close together in the same field, we cannot of course suppose that any plant would be likely to suffer from the lack of neighbors. It is not impossible, however, that rain coming at the wrong time, or some other unfavorable circumstance, might largely defeat "the best laid schemes" for cross-pollination. Indian corn, as we have seen, protrudes its ample stigmas all at once and far beyond the husks. So long do they remain thus exposed and in good condition for receiving pollen, that even if bad weather lasted some days, there would be plenty of time left for thorough pollination. Other cereals, on the contrary, open their spikelets only a few at a time and close them again after a brief exposure of the stigmas and anthers. This is doubtless necessary because of the greater delicacy of the parts. It makes the flowers, however, much more dependent upon favorable weather to accomplish their cross-pollination. Indeed, it must often prove to be impossible with many of the flowers. Hence, if the ripening of seed in these plants were made to depend entirely upon the chances of securing a cross (as is the case with certain kinds of grasses), then the farmer's crop would be very likely to suffer. Cultivators of grain naturally prefer those sorts which give the best yield. This means that the varieties which best provide for the certain pollination of every ovule are the ones most generally selected. The result is that we find in many of the cereals in cultivation as good or even better provision for close-pollination than for securing a transfer of pollen from plant to plant.

In rye the stigmas and anthers mature at the same time, and as the bracts then open widely, a good opportunity is given for either cross- or close-pollination. The amount of pollen is certainly sufficient, for it has been estimated that a single anther contains twenty thousand of these golden dustlike grains. This makes something like two hundred pounds of this powder to an acre of rye.

The arrangements for pollination in wheat, barley, oats, and rice are much the same as in rye, except that their bracts as a rule open less widely and in some cases not at all. When a flower remains closed its pollen can reach no stigma but its own, and cross-pollination is prevented. Yet it is a curious fact that in such cases there is still an enormous amount of pollen. Since we know that a single particle of pollen to each ovule is sufficient to insure its proper development, all this unnecessary production of precious material seems strangely wasteful. We can account for it only on the supposition that these flowers were originally fitted for cross-pollination and have lost the power through many ages of cultivation.

The loss of this important power may have come about partly through the continued selection of the sorts which yielded best, as already suggested. Perhaps it may have resulted in part also from the special care which these plants have received for centuries. At least it seems not improbable that plants which are made to grow in soil carefully prepared and enriched would have less need of the advantages of cross-pollination than wild plants which have to shift for themselves. However this may be, we must not argue from the facts given that cross-pollination is of small value to the offspring even of cultivated plants. Indeed we have abundant proof to the contrary in the fact that varieties most highly prized by modern cultivators — as, for example, the famous "pedigree wheats"— have been obtained through repeated cross-pollination by artificial means. The truth would seem to be that farmers are in some cases willing to forego certain advantages for the sake of securing others which they deem more important.

Ripening and Protection of the Fruit.

After pollination has been effected in one way or another, the stigmas and anthers, having now fulfilled their purpose, fall off or wither. At the same time the ovary and the ovule inclosed within it begin to undergo the remarkable changes which constitute the ripening of the grain. Nearly all the food which the plant now manufactures or has previously stored in its pithy parts is henceforth delivered to this region of rapid growth to serve as material for the transformations in progress.

What goes to the ovary wall enables it to enlarge so as to keep pace with the young seed within. The main bulk of all the food, however, is needed in the ripening ovule, or seed that is to be. As the material arrives part of it is used up at once in the formation of a little plant with tiny stem, leaves, and roots. These are all packed into the smallest space, and the whole comes to occupy a position at one side near the lower end of the seed. (Fig. 9.) The larger share of the material received is stowed away in the remaining portion of the seed, as food for the young plantlet to use at the time of sprouting.

Since in the plant body materials may be carried from place to place most readily when dissolved in the sap, the food substances which come to the young seed arrive in liquid form. Here we find them accumulating for a while, as constituents of a sweet milk-like fluid. While in this stage, the kernels are said to be "in the milk." Gradually the nutritive part of this "milk" separates from the watery portion, somewhat as curd separates from whey. At the same time fresh nutritive material is arriving to be solidified in the same manner. Finally the "milk" is entirely replaced by solid food-material which becomes in the ripened grain as hard as the hardest cheese. Thus in each seed there is packed the largest amount of food possible in the available space.

During the milky period in the ripening of the grain, the sweet and exceedingly tender kernels offer a great temptation to certain birds. Rice planters are especially troubled by hosts of bobolinks which arrive from the north just in time to do most damage in the fields. No longer the conspicuously colored songsters we know in summer, these birds have now become sparrowlike in appearance, and, as a result of their gluttony, almost too fat to fly. While in this condition, they are known as "rice-birds," and appear under that name as a delicacy in the markets. Pictures from Japan indicate that a similar bird infests the rice-fields of that region. Wheat and other grains are also known to suffer somewhat in the same way in various localities.

It has been observed that the bearded varieties of grain plants suffer less from the attacks of birds than do the awnless sorts. Hence, it would seem that awns may be the means naturally provided as a protection against these enemies. An examination of a well-developed awn of rice, rye, wheat, or barley will show it to be especially well constructed to serve as a defensive weapon. (See Figs. 22 and 24 *D*.) Not only is it sharp at the tip, but along the sides it is armed with numerous upward pointing teeth. The whole recalls the long saw-edged spears used by certain savage warriors. A little bird with short bill in trying to steal

FIG. 13. Oat plant which had been blown over and then recovered the upright position of its upper part by bends at the nodes. Brace roots are developing from the lower nodes, and two tillers have started near the base. The young inflorescence is just pushing its way out from the uppermost leaf sheath. (Original.)

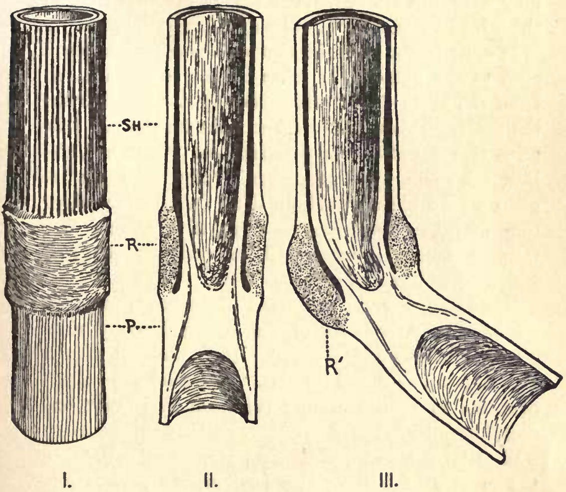

FIG. 14. I. Part of an oat stem showing swollen ring (R) at base of sheath (SH). P, place of the node. (Enlarged.)

II. The same, cut lengthwise.

III. The same, after the upper internode has been bent into an erect position from an oblique one by growth of the sheath-ring on its lower side R′. (Original.)

the kernels from a bearded spike of wheat, rye, or barley, could hardly avoid rubbing tender parts of its head against the sawlike edges of many awns. The entire absence of such defensive weapons from maize may doubtless be accounted for by the fact that its thick husks generally afford ample protection.

It must be remembered that whatever food-material goes to the building of awns is just so much taken from the store which otherwise might be laid by in the seeds. This may in part account for the fact that some of the best-yielding varieties of wheat, and the like, are entirely without awns. (Fig. 26.) In regions where birds would do little damage, or where they may be readily scared away, it is natural that farmers should encourage those varieties of grain which make less awn and more seed.

The ripened grain or kernel of any corn plant, as we have seen, consists of the enlarged ovary completely filled by a single seed. It is thus not merely a seed, but a seed and its case. The seed case, moreover, fits so tightly around the seed, that the "seed coat," or outer layer of the seed, unites with the ovary wall to form a hard, protecting layer or "hull." In the process of milling this indigestible part is separated and forms the main bulk of "bran," while the seed food is ground into meal or flour.

Sometimes as in oats (Fig. 18) and common barley, the precious contents of the grain are still further protected by having one of the innermost bracts of the spikelet wrapped so tightly about the seed case as to seem almost a part of the kernel. In rice two hard bracts inclose the ripened grain and fall off with it. These coverings are of special use after the grain has left the parent plant, and must shift for itself.

Scattering and Planting of Seeds.

With grasses that grow wild, the future welfare of the offspring depends largely upon the seeds being carried to some new locality. For, plainly, if the seeds should sprout in the immediate vicinity of the parent, the young plants would have to live upon soil from which the substances most needed for their growth had already been largely exhausted. Let them be carried to a distance, however, and there would be a chance of their securing a more favorable place of growth.

In order to obtain this benefit for their offspring, wild grasses provide various means for securing the transportation of their ripened seeds. Some of them develop tufts of hair, long streamers, and balloonlike coverings, or other special arrangements for catching the wind. Aquatic grasses provide a boatlike affair in which the seed may float away. Certain land forms have hooked or barbed projections on bracts surrounding the seed, which make thus a sort of burr. This, catching into the fur or fleece of a passing animal, may be carried a long way before it is rubbed off. Still other methods might be mentioned by which different wild grasses send their seeds on a journey, but enough has been said to show that this important provision for their welfare has by no means been neglected.

When we turn to our cultivated cereals and ask what arrangements they have for dispersing their seeds, we find that in this matter they present a marked contrast to the other grasses. Instead of taking advantage of the carrying power of wind, water, or passing animals, they generally seem to be doing their best to prevent such natural agencies from removing the seeds at all. The kernels of maize, for example, are attached so firmly to the cob and inclosed so tightly by the husks that considerable manual labor is required to separate them from the plant. With the other grains, as we know, severe threshing is necessary to dislodge the kernels from their coverings. Sometimes this habit of holding their ripened seeds leads to a curious result. If, because of continued wet weather, a farmer is unable to harvest his wheat or barley, he may find the kernels sprouting in the heads, and pushing forth clusters of little green leaves from every spikelet. A wild grass could scarcely be found in such a predicament.

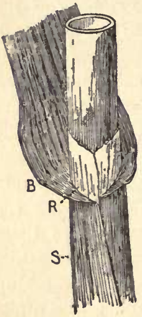

FIG. 15. Oat. Part of leaf and stem showing the rain guard (R) where the blade (B) and the sheath (S) join. (Original.)

The reason for this remarkable contrast between wild grasses and those cultivated for their grains is probably not far to seek. We know that a farmer can derive most profit from the sorts which hold their seeds until he is ready to harvest them. Naturally, also, he prefers to manage the sowing himself. From the earliest times, therefore, intelligent growers of grain would have been likely to plant only those sorts which hold their seeds long enough for the farmer to gather them, and only these would stand any chance of benefiting from human care. Consequently the cultivation of grains must have continually discouraged whatever methods of dispersal these plants may have had in the wild state. It is true that as soon as any kind of grain lost the power of scattering its seeds, it became entirely dependent upon man's care for the continuance of the race. Yet through such dependence it must receive great benefit. Henceforth, upon its welfare would depend in large measure the welfare of man, and consequently it would have bestowed upon it man's intelligent care through which the highest possibilities of its kind would be developed.

Certain sorts of corn plants have come to depend more than others upon human agency for the sowing of their seeds, just as in the matter of pollination the influence of culture has been more marked in some cases than in others. Thus our maize plants if left to themselves in the field would not produce another crop. The same is true of most sorts of wheat and barley. These plants are known only in the cultivated state, and botanists believe that the original wild forms may have died out entirely. Rice, rye, and oats, on the contrary, often sow their seeds about the fields in which they are cultivated, and in favorable localities they thus establish themselves as wild plants. Our cultivated varieties of oat are believed to be merely improved forms of "wild oat," which grows as a weed in the same fields. This close association of the wild with the cultivated form is accounted for on the supposition that of all the cereals the oat has most fully retained its original power of seed dispersal, and hence is most apt to relapse into the wild condition whenever opportunity offers. Such wild-growing forms of corn plants are of interest as showing us how the ancestors of our cultivated grains used to provide for the planting of their seeds before farmers came to help them.

The fruit of the wild oat mentioned above differs from that of the cultivated sort in three particulars, whereby it takes advantage of the carrying power of wind. Thus, as will be seen by comparing Figs. 18 and 19, the wild oat has a smaller and consequently lighter grain, which can therefore be more easily blown away. Moreover the surface exposed is made larger by the longer and rougher awns and the numerous long, bristly hairs developed on the inner bracts. These peculiarities of the wild plant are plainly the ones which serve for the dispersion of its seeds, and are furthermore just the ones that cultivation would discourage.

Another peculiarity of the wild oat is the marked twisting of the awn below the sudden bend. When moistened, the twisted part uncoils; upon drying, it coils again; and this uncoiling and coiling may be repeated many times. At each coiling, the free part of the awn is made to sweep around like the hand of a watch, or, if the tip of the awn is held fast, then the main part of the fruit is forced to revolve several times on its axis. When one of the separated fruits carried away by the wind falls at last to the ground among grass or stubble, the peculiar movements of the awn help to bury the seed in the soil. At the first increase of moisture the awn revolves till its tip is stopped by some stalk or clod; then the twisting motion is transmitted to the lower part of the fruit, which, being sharp and beset with upward-pointing bristles, slips forward with ease but not backward even when the motion of the awn is reversed. The result is that with every twist the seed part is forced further and further into the earth. Country boys have noticed that a ripe spikelet of the wild oat, from the peculiar features described, bears a curious resemblance to an insect, not only in general form but also as imitating the struggles of an insect when thrown into the water. This resemblance they take advantage of by using the fruit instead of a fly in fishing for trout.

Rice, as we know, is a plant that grows in the water. We should expect, therefore, that like many other aquatic grasses, it would make use of the floating power of water to carry its seeds to new and favorable localities. If, however, we place some ripe spikelets of cultivated rice in water, we find that all of them sink immediately, except a few which have only imperfect grains within the husks. These exceptions show that if the grains of the other spikelets were not so large and heavy the spikelets would not sink. In wild rice the grains are considerably smaller and lighter, and the husks hold so much air that the ripe spikelets are doubtless able to float. The increased size and weight of the cultivated rice grains are plainly results of cultivation.

Rye, wheat, and barley, which resemble one another so closely in the general form of their spikes, give evidence of having closely similar methods of seed dispersal in the original wild state. In the wild form of rye, the rachis of the spike becomes very brittle at the nodes as soon as the fruit is ripe. The same is true to a slight extent of certain sorts of wheat and barley. As a result of this brittleness, when the spikes are threshed around by the autumn winds, the rachis breaks into a number of short sections each with a single spikelet attached in rye or wheat, or with a spikelet cluster in barley. A wind which is strong enough to break the spike into sections will have carrying power enough to transport the section, with its seed or seeds, no little distance from the parent plant. With cultivation, the rachis would gradually lose its brittleness, and now we find this peculiarity almost entirely absent from the varieties which farmers prefer.

So long as botanists knew of no wild plant closely

Fig. 16. Oat. *A*, **upper part of inflorescence.** *B*, **a single spikelet in flower, with the bracts spread somewhat apart.** *C*, **one of the outer bracts.** *D*, **an inner bract bearing an awn.** *J*, **pistil.** *G*, **lodicules.** *C*, *D*, **and** *J*, **enlarged. (Nees.)**

resembling maize, it was scarcely possible for them to arrive at any satisfactory idea of the original peculiarities of the fruit, however sure they might be that much change had been effected by cultivation. Fortunately there was discovered a few years ago, in the mountains of Mexico, a wild plant closely resembling our maize. The Indians call it "coyote corn," because the coyotes or prairie wolves are especially fond of it. It is so much like cultivated maize that botanists believe it to be the same or very nearly the same as the wild ancestor of our familiar corn. The most marked difference between the coyote corn and the cultivated maize is in the fruit. As shown in Figure 11, the ear of this wild corn is inclosed in husks like those of cultivated maize, and has its small pointed kernels borne on a thickened rachis or cob. But this cob is divided into a series of segments by deep cuts extending inwards and upwards from just below the bases of the kernels. When the fruit is ripe the ear breaks easily into sections in much the same way as the spike of rye or wheat. These sections, however, are inclosed by the husks, and so would seem to be prevented from being blown away like the spike sections of the plants mentioned. How shall we account for this hindrance to scattering the seeds? Most probably the explanation is this: The husks form a sort of pod, vase-like in form and open above, which holds

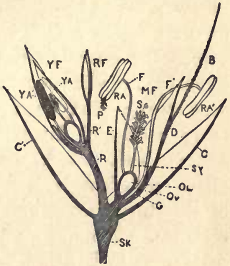

FIG. 17. A spikelet (similar to *B*, FIG. 16) cut lengthwise to show the inner parts. Somewhat diagrammatic. SK, stalklet; R, R', its continuation as a little rachis within the spikelet; C, C', outer bracts; M F, mature flower; Y F, young flower not yet opened; R F, rudimentary flower or pair of bracts with no floral organs within; D, bract with awn (B); E, inner bract; G, lodicule; F, F', filaments bearing anthers (R A, R A'), from one of which pollen is falling (P); SG, stigma; SY, style; OV, ovary, containing an ovule (OL); Y A, a young anther; Y A', a similar one cut lengthwise to show the pollen forming within. (Original.)

and conceals the loosened sections of the ear. A wind just strong enough to break apart the sections of a rye spike and carry them away would only rattle the maize sections around in their pouch. Such a wind, however, could be of scarcely any service to the maize in carrying to a distance its much heavier kernels. Hence the husks keep the kernels from being scattered by any wind but one of considerable power. A very strong wind must shake the whole plant vigorously back and forth, and thus will hurl the fruit sections well out of the husks through the opening above and often high up in the air. The mere force of this throw must carry the kernels a considerable distance, while the strong wind will help them still further on their journey.

The fondness of the coyotes for the fruit of this plant suggests that the kernels are doubtless scattered also to some extent by these animals when they tear off the husks. In this case, of course, the kernels drop rather near the parent plant. There are certain birds, however, which may sometimes unwittingly do the plant a good turn by carrying the kernels unharmed for a considerable distance and leaving them in a place favorable for growth. These birds are thieves who have discovered the secret of the corn's rich treasure, and not content with eating all they can hold carry away many kernels, much as squirrels do with nuts to hide them for future use. As with the squirrel so with the bird, the thief may be killed before he has a chance to enjoy his plunder. Then such of the seeds as he had placed in favorable situations would have a chance to grow into new plants. Wolf and bird may be regarded as playing very imperfectly and quite unintentionally the part of farmer.

It has been observed that half-starved Indians sometimes rob the stores of nuts and corn which birds or other creatures have collected. This has led to the suggestion that the aborigines may have learned the use of maize from the example of these wild animals.

Much the same sort of service that birds and beasts render to maize is performed for wheat and barley by grain-loving ants which live in certain warm parts of the Old World. It is to the remarkable habit which these insects have of storing grain that reference is made in the famous passage from Proverbs (vi. 6–8):

> "Go to the ant, thou sluggard;
> Consider her ways, and be wise:
> Which having no chief,
> Overseer, or ruler,
> Provideth her meat in the summer
> And gathereth her food in the harvest."

Throughout Palestine so much importance has been attached to the finding of these hoards of grain that rules as to ownership have been laid down in the great Hebrew law-book known as the Mishnah. Sir John Lubbock further tells us that "various commentators, including the celebrated Maimonides, have discussed at length the question whether such grain belonged to the owner of the land or might be taken by gleaners, giving the latter the benefit of the doubt. They do not appear to consider the rights of the ants."

Harvesting ants are common in other warm parts of the Old World and in the warmer regions of America. They do not confine their attention to cultivated cereals, but collect largely from wild grasses. In Texas what are known as "agricultural ants" make special provision for the growth of a wild grass called "ant rice," and regularly harvest and store the grains for winter use. These facts indicate that before wheat and barley came to be cultivated they may have been helped not a little in the favorable planting of their seeds by the industrious efforts of harvesting ants.

The Infant Plant and its Food.

We have seen how every part of a full grown corn plant contributes in some way to the production of offspring well fitted like the parent to lead a prosperous life in the field. We have learned, moreover, that wild corn plants in order to prosper need to adopt precautions and build structures which become largely unnecessary as soon as the plant comes to profit by human care. At the same time such care, we know, favors in other important ways the production of as fine and as many offspring as possible. Centuries of husbandry have enormously increased the quantity of seed food provided for each little plant, and also the total yield from a single seed.

Surely the vegetable kingdom has no greater marvel to show than a kernel of corn. It represents the joint achievement of man and nature working together for untold generations upon this kind of plant to promote the most perfect provision for its offspring.

In order to better appreciate how fully the needs of the infant corn plant are provided for by the parent, we must examine somewhat more thoroughly than before the contents of the seed. We have seen that the germ is formed near the base of the seed at one side, while in the remaining space food materials are accumulating. This food, arriving in fluid form, becomes finally changed into a hard, solid mass as the nutritive substances take more and more the place of the conveying water. There is, moreover, a loss of the sweetness at first observed, — a loss which becomes perceptible when we compare the taste of a kernel "in the milk" with one fully ripe.

The obvious conclusion from such an experiment is that what arrives as dissolved sugar is somehow changed within the seed into another substance. Chemists using more accurate tests find that in the forming seed, as the sugar disappears, its place is taken by starch. This, as is well known, differs from sugar in having no sweet taste, and in not being soluble in water. A similar change of substance is found to occur in other important constituents of the seed food, making them as insoluble as starch.

An example of the most valuable of these food substances is afforded by what farmer boys call "wheat gum." It is a favorite practice of theirs after harvest to obtain this substance by chewing a small handful of the ripe wheat kernels. In so doing they perform a sort of rough chemical analysis of the seed food, which is not a little instructive. The "gum," which is their reward for patient chewing of the kernels, is well named, since it lacks none of the qualities essential to a perfect "chewing gum." That is to say, not only does it retain for some time a pleasant sweet taste, but it is soft and yielding, holds well together, and no amount of chewing will make it dissolve. When taken from the mouth it is found to be remarkably elastic, stretching and springing back like rubber. It also shows itself as adhesive as glue. In consequence of its glue-like properties it is named "gluten." As we shall see later, it is because wheat contains a considerable amount of this tenacious gluten that we are able to make raised bread from wheat flour. Gluten, moreover, is of the highest nutritive value. In this regard it is equal to the curd of milk, white of egg, or lean meat. Like them it belongs to the class of substances known as *proteids*, which form the chief part of our flesh and blood. In the seed food of the other corn plants proteids also occur; but these for the most part lack the tenacity and elasticity that make wheat gluten so valuable in bread.

Besides the starch and proteïds contained in corn seeds, there is present a small amount of fatty oil; these are the principal food materials upon which the infant plant must depend for its nutriment. Yet we know that these can form no part of a watery sap such as a plant needs to nourish it. How, then, can the infant wheat plant profit in any way from these insoluble substances packed in the seed?

Before attempting to answer these questions let us inquire how a similar difficulty is overcome in our own bodies. We know that food cannot nourish us unless it gets into the blood; and only watery fluids can pass through the walls of the stomach. Whenever we take into the stomach food containing gluten, it comes at once under the influence of a peculiar substance called *pepsin*. This causes insoluble proteids to undergo a curious transformation. However solid or tenacious they may be, mere contact with the pepsin dissolved in the juice of the stomach gradually changes them into readily soluble substances known as *peptones*. Passing now easily into the blood the peptones may be carried to any part of the body, there to be built into solid flesh. Substances like pepsin, which are believed to have the power to transform other substances without being themselves transformed, are called *ferments*.

In the mouth is formed another ferment, called *ptyalin*, which has the power of changing starch into sugar. In the farmer boy's separation of wheat "gum," ptyalin plays a most important part. We may thus explain why the kernels become sweet with

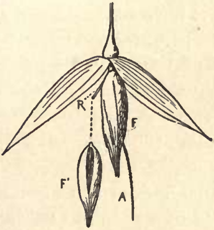

Fig. 18. A spikelet of cultivated oat in fruit. F, the awned inner bract swollen with the ripe grain within; A, awn; F′, another ripe "oat" separated from the little rachis (R) and turned to show its inner face where the edges of the bract inclosing the grain are seen not quite meeting at the centre. About natural size. (Original.)

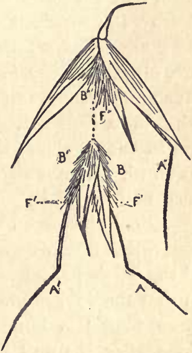

Fig. 19. A spikelet of wild oat in fruit. F, F′, two fruits separated from the other (F″); B, B′, B″, bristles; A, A′, A″, awns. About natural size. (Original.)

chewing, and why the sweetness finally disappears: As the starch, which forms the main bulk of the wheat grain, becomes gradually changed by the ptyalin into sugar, it dissolves in the saliva, is then swallowed, and finally passes into the blood through the wall of the stomach. The sweet taste continues until all the starch mixed with the gluten has been changed into sugar and carried away.

Ferments having much the same power of changing proteids into peptones and starch into sugar are found in the ripened grains along with the seed food. These ferments are ready to act as soon as the grain is in condition to sprout. Let us now see how this process of sprouting or germination takes place.

A ripe kernel of any grain, as we know, is dry and hard, and the germ within is apparently lifeless when it leaves the parent plant. Nor can it be made to show any signs of life except it have sufficient moisture, air, and warmth. The temperature need not be much above the freezing point of water, or far below what to us feels hot. There should be enough moisture to enable the seed to become well saturated and softened, but not so much water as to prevent free access of air. When placed under these favorable conditions the first change to be noticed is a forcible absorption of moisture indicated by a prompt swelling of the whole kernel. So forcibly is the water taken in that the swelling is able to overcome a pressure of more than two hundred pounds to the square inch. Soon after the seed has absorbed all the water it can hold, the infant plant begins to show signs of life. It is as if the disturbance of its cradle had at last awakened it from a long sleep, and fancy suggests that the little thing must be hungry. If so, the food is at hand, and now all is in readiness for changing the solid materials into liquid nutriment as fast as the plantlet's needs require. This is accomplished by means of several ferments very much like the two already described. Their liquefying action begins on that part of the seed food lying nearest to the germ.

If we look now at the germ of maize as shown in Figure 9, we find that the part lying in contact with the seed food is in form so different from all the other parts as to suggest its having a special use. This curious shield-shaped part is called the *scutellum* (*sc*). On the side in contact with the seed food the scutellum is expanded so as to present as much surface as possible, while its connection with the rest of the germ is at the junction of the young shoot (*st*) and the young root (*w* below). As the plantlet enlarges in germination we find the seed food gradually exhausted, until finally only the empty "hull" is left. Plainly, therefore, the purpose of the scutellum is to absorb the liquefied food coming in contact with its broad surface, and then to conduct it toward that part of the germ whence the nutriment may be most readily distributed to the growing organs above and below. In all the other grains the scutellum is much the same as in maize, only smaller.

The first part of the germ to break through the protective covering is the main root (*w*, Fig. 10 I.). This is soon followed by an upward pointing cylinder (II. *b*) made up of tiny leaves in tubular form, one within another. At about the same time appear from the side of the little stem the secondary roots (III. $w,'$ w'', w'''). Such roots rapidly increase in number and importance.

Soon after a root emerges it is found to be nearly covered with delicate hairs, which adhere firmly to any particles of soil with which they may come in contact. Such root-hairs henceforth perform the work of absorbing water into the plant. The tip of the leafy shoot, at first pale, begins to turn green as soon as it reaches the sunlight. This is a sign that the young plant is making food on its own account; but it is not yet required to depend entirely upon itself.

There is considerable seed food remaining when this stage is reached. This generous supply enables the plantlet to extend its roots and leaves much farther in a short time than would otherwise be possible. When at last the reserve supply is exhausted the infant plant is well able to take care of itself. It can thus enter vigorously upon a sunny life in the fields, — a life leading finally to the production of well-developed offspring.

V. The Advantages of Cereals as Food-Plants.

From what we have learned of the life of cereal grains it will now be easier for us to understand why they are the most useful of food-plants. A few well known facts will help us to appreciate more fully their importance to civilization. The food of savages is obtained principally by hunting and fishing, and by gathering roots, fruits, and seeds of wild plants. The supply of food which may be thus found is so limited in any region that only small and wandering tribes can live in this way. Large and strong nations are possible only where food is made abundant by domestication of plants and animals. Moreover, since the domestic animals most useful to man live almost exclusively on vegetable food, we see that it is the plants which primarily count. Wild plants, it is true, may largely serve as forage for cattle, sheep, and the like; but forage can seldom be had throughout the year, and the best results in raising animals are never attained except where fodder is grown for them. Hence increased dependence upon animal food means generally not less but greater dependence upon cultivated food-plants.

Of these, as we know, corn plants have always been preferred by the greatest peoples throughout the world. The main reasons for this preference are not far to seek; they relate chiefly to the yield, separation, bulk and keeping of the grain. That is to say, the superiority of cereals depends upon their having important advantages over all other food-plants, — not that in any one particular corn plants may not be equaled by others, but that every other food-plant lacks one or more of the great advantages which corn plants combine. These fortunate peculiarities we may now consider.

Yield.

The foremost advantage of corn plants is the prompt and generous return they make to man for the care he bestows upon them. Even when growing wild or with little care, plants of this sort yield, as we have seen, a considerable amount of food, while intelligent cultivation increases the yield enormously. This is well illustrated by the following case, which the ancient writer Pliny tells of as coming up before the magistrates in Rome.

A farmer named Cresinus had astonished his neighbors by reaping much larger crops of grain from a very small farm than they had been able to raise in extensive fields. Moved by envy, they brought him to trial on a charge of sorcery. "In answer to this charge Cresinus produced his efficient implements of husbandry, his well-fed oxen, and a hale young woman, his daughter, and pointing to them exclaimed, — 'These, Romans, are my instruments of witchcraft, but I cannot here show you my labors, sweats, and anxious cares.'" Could the enterprising Cresinus have looked into the future and seen the stupendous grain crops produced on our best farms to-day, he would doubtless have found the advance quite as mysterious as his neighbors found his improvement on what they had done. Nor have we any reason to suppose that our farmers have reached the limit of progress in this direction. On the contrary, it seems to expert students of the question that the farmers of the future are sure to attain an increase in the yield of corn plants many times greater than the best results thus far achieved.

The extraordinary yield of cereals is plainly a result of their remarkable fitness for life in the field. This fitness, as we have seen, is shown especially well in their ability to take fullest advantage of every opportunity offered to increase their facilities for food-making. The open field affords just the conditions most needed for this work; that is to say, abundant sunshine, sufficient moisture, and least interference from overshadowing plants. The slender, upright form of their green parts permits grain plants to grow well even when crowded rather close together. Not only can many stalks then grow up to good advantage from a small area of soil, but the spreading of weeds among them is thereby discouraged. All this favors rapidity of growth and helps to make the cultivation of corn plants easy. Rapid development is especially important in northern regions where the growing season is very short. In Lapland barley is harvested about six weeks after planting, while in such warm countries as Spain the farmers reap two crops of barley within the year.

Fig. 20. Rice. P, upper part of a rice plant, reduced in size. S, spikelet. L, ligule. L and S, natural size. (Martius.)

Separation.

Besides being at once exceptionally productive and easy to cultivate throughout a wide range of climates, corn plants store their nutriment in a form especially easy for man to obtain. Most other food-plants are found to give more trouble than do the cereal grains in one or more of the processes by which the nutritious parts are separated for man's use. Thus, their manner of growth makes the reaping of the grain much less laborious than the harvesting of "root-crops," which require digging, or of pod plants, such as peas or beans, where hand-picking is generally required. The arrangement of parts in the ripened ear makes the separation of the kernels a much simpler matter than the removal of nut meats from their husks and shells. Moreover, on account of the delicacy of the hulls of grains it is particularly easy to remove the edible portion of the kernels by milling (*i. e.* grinding and sifting), and so to render the final preparation of the seed food as simple as possible. In this way, so fully is the most nutritious part of the kernel freed from all indigestible matters that cereal foods when eaten are found to be among the very easiest for the digestive organs to manage.

To the question, Why do corn plants yield their kernels so readily to man? the answer plainly is: Because at first they confided their offspring to the wind for transportation. If we ask, Why is the seed food so easy to separate and digest? the answer is equally plain: The seed food is stored by the *side* of the germ. Therefore, simply crushing the grain will free the nutritive part both from the germ and from the hull. Moreover, since, in sprouting, the infant plant needs to have its food supplied promptly in liquid form, it is necessary that the nutritious materials should be easy of digestion ; and as the digestion of these substances depends on the action of much the same ferments both in the grain and in the human body, we see that what is easy for the one is easy for the other.

Bulk.

Another important advantage which the grains have for us is that they contain much nutriment in little space. In this respect they surpass nearly all the other vegetables used as food. If we compare, for example, the food value of equal weights of wheat grains and potatoes, we find a remarkable difference between them. Wheat contains over three times as much energy food (starch, etc.), and more than five times as much muscle-forming material (gluten and the like), as we find in potato; while in the potato there is over five times as much water as in the wheat. Thus, to supply our need for muscle-forming materials, one pound of wheat is better than five pounds of potato. Consequently, when food has to be carried from one region to another, grain plainly possesses immense advantages, both in the matter of weight and of bulk. By the use of grains as food, travelers are able to make journeys which otherwise would be scarcely possible. So also has it been with the great armies of the world in extending their conquests.

We may account for the superiority of grains in this respect, likewise, by referring again to the needs of the plant. Infant corn plants in the wild state are, as we have seen, extensive travelers, while such buried off-shoots as potatoes we know to be stay-at-homes, sprouting where they were formed. We should expect, therefore, that potatoes would be large and full of water, since weight and bulk have no disadvantages for them. For kernels of grain, on the contrary, lightness is plainly essential so long as they depend on the wind to carry them. Hence we find the infant corn plant provided for its journey with a ration composed of the most nutritious food-stuffs, in a form as compact as possible.

Keeping.

Finally, it should be noticed that the extreme dryness of the kernels, taken in connection with the fact that only a very small amount of oil is present in the seed food, gives another advantage to the offspring of corn plants and increases their value to mankind. Seed food which is moist or is rich in oil must be used within a comparatively short time, or it will be found to have turned rancid or to have become otherwise spoiled. The oily kernels of various nuts, for example, have this drawback. Grains, on the contrary, if properly stored, may be kept unchanged for very many years. Thus, by wise foresight, man is enabled to make sure of his daily bread even through years of famine. That this advantage was very early appreciated among ancient peoples is well shown by the story of Joseph in Egypt (Genesis xli.).

In our own day the storage of grain in prosperous regions during seasons of plenty has proved vastly important as a safeguard of civilization. Famine-stricken peoples in various parts of the Old World have often owed their lives to the breadstuffs sent from American granaries. With regard to the corn plants themselves, even when wild, it is easy to see how the good keeping qualities of their seed food would sometimes be of benefit. After the kernels have been carried away by the wind it cannot always happen that they will come at once under the necessary conditions for germination. If such kernels can safely wait a long while before sprouting, their chance of final success is plainly increased. In this respect, therefore, the seeds of corn plants have an advantage over many others which must die within a few months if they fail to germinate.

Summary.

The chief advantages of cereals as food-plants have now been mentioned. Without exception we have found that the features which make corn plants especially useful to man are of benefit to the plants themselves as dwellers in the field. We may conclude, therefore, that their great usefulness to us is mainly due to their wonderful fitness for field life and their unstinted provision for the welfare of their offspring. It is chiefly because they provide so well for their young that man has come to care for them and multiply their kind. Man takes for his share of their produce the surplus of seeds which the wind once wasted, but by the rest he makes their life more and more abundant. Each kind, at first growing only within comparatively narrow bounds, now under man's care flourishes far and wide. To corn plants have been given the greater part of the richest fields of the earth.

VI. Wheat, the King of Cereals.

Throughout the civilized world, wherever wheat will grow or where the people are not too poor to buy it, this grain holds the foremost place. It has always yielded "the staff of life" to the greatest and most powerful nations since the beginning of history.

Wheat has been so long and so widely cultivated that the question of where it first grew wild is one very difficult to answer with entire certainty. It seems highly probable, however, that the native home of wheat was in the region of Mesopotamia. (See map, p. 103.) Botanists believe also that wheat was first cultivated in the fertile valley of the Tigris and Euphrates. As a centre from which to spread most widely and rapidly, this region would surely have been the most fortunate possible, since it lies in that part of Asia which is within easiest reach of both Africa and Europe. Hence from no other locality could this invaluable food-plant have been carried so readily into the other parts of the Old World where civilization might best advance. There seems good reason to believe that civilization first arose in the home of wheat, and that the highest civilizations have always depended in their conquests upon the king of cereals.

We know that in Palestine and in Egypt wheat was cultivated long before the dawn of history, and that in very early times its culture had extended eastward to Persia, India, and China, westward to Greece and Rome, and northward or northwestward into central Europe. Wheat was first brought to the New World soon after the discovery of America by Columbus. To-day the United States produces more wheat than any other nation.

This grain holds the highest place among corn plants because only from wheat flour can raised white bread be made. The whiteness of wheat products has long been recognized as their most characteristic attraction. Indeed "wheat" and "white" come from

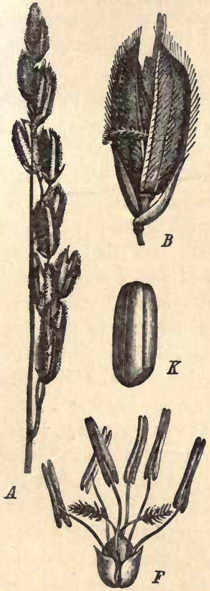

Fig. 21. Rice. *A*, **part of inflorescence.** *B*, **a spikelet in flower.** *F*, **a flower showing six stamens, a pistil with ovary, two styles and stigmas, and a pair of lodicules at the base.** *K*, **a kernel. (Nees.)**

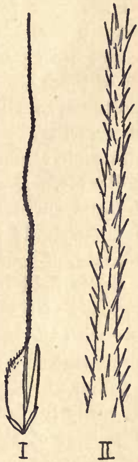

Fig. 22. Rice. I, a spikelet of a bearded variety, showing the long awn developed from the tip of an inner bract. Natural size.

II, a part of the awn, enlarged, to show the upward pointing barbs. (Original.)

the same word in the ancient Anglo-Saxon language. It still remains true with us that white bread is always wheat bread.

The raising of bread, as already stated, depends upon the presence of gluten. As raised bread is most commonly made the flour is mixed with a little water and yeast to form a stiff dough, which then is vigorously kneaded so that the yeast may be well distributed throughout the mass. This accomplished, the dough is put in a warm place to "rise." The conditions are now favorable for the yeast to begin its work. What this work is may be understood from the fact that yeast contains a ferment, which, like some of those already mentioned, acts on starch. Yet while these, as will be remembered, simply turn starch into sugar, the yeast ferment has the power to make, from starch, alcohol and an odorless gas known as carbon dioxide. Each particle of yeast, made warm and moist and surrounded by starch, becomes thus a tiny gas factory. If there were nothing to prevent, the gas would, of course, escape. But in the wheat dough the gas is held in little cavities by the gluten. As the gluten is elastic these cavities become larger and larger with the pressure of the gas within. It is this enlargement of innumerable small cavities throughout the dough which makes it "rise" into a light spongy mass ready for baking.

The heat of the oven stops further action of the yeast, enlarges somewhat the cavities in the dough by expanding the gas, hardens the gluten so that the cavities cannot shrink, and then drives off the greater part of the moisture, alcohol and carbon dioxide. At last the crust comes to a perfect brown, indicating that the best flavor of the wheat has been developed. The final result is a loaf of wheat bread, the highest type of human food.

The peculiarities of wheat gluten also make possible such valuable foods as macaroni, which consists very largely of this substance. The same is true in general also of crackers or biscuits, especially the tough, long-keeping sort known as ship-biscuit or hard-tack, which forms the chief vegetable food of crews at sea. In general it may be said that the innumerable articles of human food which consist wholly or in part of wheat owe their special excellence to the peculiar properties of the gluten present.

The starch which forms, as we know, the main part of the wheat kernel is likewise of great value, not only in the foods above mentioned, but also by itself when separated as a pure product. Wheat starch is extensively used as a material for paste or sizing in various manufactures.

Just as the inner part of the kernel is invaluable for human food, so the outer part or "bran," which includes bits of hull and adhering particles of seed food, is one of the very best feeding stuffs for domestic animals. The straw, both green and ripe, is also widely used for the same purpose.

On the immense wheat farms of the far West, the straw is used in curious ways. At harvest it supplies the fuel for great steam threshing-machines as they work in the fields. One part of the wheat plant is thus made to help prepare another part for market. In some regions the straw is used for building barns in which to store the grain. This is accomplished by making solid bales or blocks of the material under great pressure and piling them like stones to form a thick, substantial wall. A roof, perhaps thatched with straw, completes the structure.

Not the least important use of wheat straw is as material for the finest kinds of straw hats and bonnets. In Italy an especially slender variety of wheat is grown for the purpose by sowing very thickly in poor soil. From straw thus raised the famous Florentine or Leghorn hats are manufactured. Stouter kinds of wheat afford material for hats made of coarser braids.

Thus we see that every part of a wheat plant is put to important and remarkably varied uses. But few plants besides wheat can be said to furnish food, fuel, shelter, and clothing.

VII. Oats, the Grain of Hardiness.

It is told of an Englishman, who was fond of poking fun at the Scotch, that one day he saw a Highlander with a bag of oats, and remarked, "There 's what feeds horses in England and in Scotland feeds men." "True enough," replied the other, "and that 's why ye 've such fine horses and we 've such fine men!" The Scotchman's retort showed no less wisdom than wit, for oats have long been the favorite food of the hardiest peoples of northern Europe, and this grain is generally recognized as the most strengthening fodder for hard-working animals.

Oatmeal is found to contain more proteid or muscle-forming substance than the average wheat flour. The proteid of oats is inferior to wheat gluten only in being somewhat less digestible. In fatty material oats are the richest of all the grains.

For northern peoples this grain has the advantage over wheat that it will grow at its best in cold climates. But it does not ripen its kernels well in regions as far south as the Mediterranean sea, where wheat seems thoroughly at home.

From these and other facts botanists conclude that the original home of oats was most probably in cen-

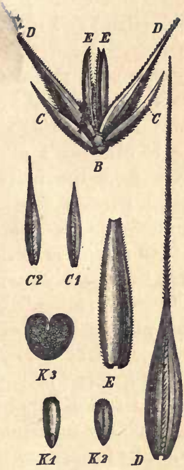

FIG. 24. Rye. B, a single spikelet showing its two flowers. C^1, C^2, outer bracts. D, inner bract with awn at tip. E, inner bract without awn. K^1, kernel viewed from the germ side. K^2, the same viewed from the grooved side. K^3, the same enlarged and cut across. (Nees.)

FIG. 23. Rye, inflorescence. (Mull-Guyot.)

tral and eastern Europe, extending perhaps into western Asia. (See map, p. 103.) So far as may be judged from ancient remains the cultivation of this grain first began in middle and northern Europe, long after the introduction of wheat but before civilization was established. It is not mentioned in the Bible, and seems to have been entirely unknown in ancient Assyria and Egypt. To-day the cultivation of oats has extended eastward to China and westward to the United States and Canada, where large crops are now raised. In Scotland and Iceland oats yield the chief vegetable food.

Since good raised bread cannot be made from this grain, it is mainly used in the form of meal cooked either as a porridge or baked into flat cakes. Much use is also made of the kernels, whole or crushed, freed from the hulls and cooked like rice. Such hulled kernels are known as "groats" among the Scotch, who depend on them very largely for food. It is in reference to this article of diet, as characteristic of these hardy people, that the quaint name, "John o' Groat's House," has been given to the extreme northeastern point of Scotland. The "oatmeal" so widely used as a breakfast food in America is more truly "groats," or "grits," than meal.

The straw of oats has important uses. As a fodder and bedding for horses and cattle it is generally preferred by farmers to the straw of either wheat, barley, or rye. Manufacturers of coarse paper and pasteboard use considerable quantities of oat straw. It is also one of the most useful sorts for packing and for filling mattresses.

In many localities oats are grown to be cut green as hay. In warm regions, such as our Southern States, where the ordinary hay grasses do not flourish, oats are successfully cultivated for this purpose, because the stalks and leaves grow luxuriantly, although the kernels are poor.

The worst enemies of the oat are heat and drought. Its hanging spikelets shed the rain, and wind and cold can scarcely harm it. It is the grain of hardiness; for not only is it the hardiest of corn plants, but it is the one which forms the main support of hardy northern peoples.

VIII. Rye, the Grain of Poverty.

Rye will grow and produce a fairly good crop where the soil is too poor or the climate too hot or too dry for any other cereal to thrive. Such conditions are found over the greater part of northern Europe and Asia. In these vast regions, therefore, rye is the staple bread-stuff, and forms the chief food of the peasant classes. Indeed, it would seem that a large part of northern Europe and Asia could scarcely have become populated as it is to-day except for the possibility of growing rye on poor soil.

The original wild form of this grain is believed by botanists to have been native to mountainous or mostly dry localities, in the south of Europe and extending perhaps to central Asia. The native home of rye would therefore seem to be in a region between the home of oats on the north and that of wheat on the south. (See map, p. 103.)

There is no reason to suppose that the great peoples of antiquity were acquainted with rye. The name occurs, it is true, in our Authorized Version of the Old Testament (Exodus ix. 32, and Isaiah xxviii. 25), but, as shown by the Revised Version, the Hebrew word at first translated "rie" is now known to mean "spelt," which is a peculiar kind of wheat.

The cultivation of rye probably first began in southern Russia and Siberia, whence it extended to other parts of Europe during the Christian era. From Europe it was brought to America by the early colonists. Among the peasantry of Germany and of Russia, a dark-colored bread, tough and coarse, is made of rye meal or bran. This forms their most important food. In Sweden rye grows especially well, and bread made from the flour is the favorite food of all classes. Rye is less nutritious than wheat or oats, but generally contains more proteid than either barley, rice, or maize.

During the early history of our country rye was much used because of its ready growth on soil not well fitted for other grains. The meal, mixed with that of Indian corn, made a "brown bread" similar to that still widely enjoyed in New England. Another use for which rye largely served was the making of whiskey.

While rye has continued to be raised in considerable quantities for the making of whiskey, its use for food in this country has come to be very small in comparison with that of wheat, oats, or maize. On worn-out or thin soils it is grown somewhat extensively as a green-forage crop. When ripe the straw becomes the poorest for fodder of any cereal straw, because it is then the most harsh and tough. These very qualities, however, combined with unusual length in the stalks, make rye straw the best for such purposes as packing, and bedding for horses and cattle, and as material for cheap straw hats, straw paper, and straw pasteboard. Such large quantities are used in these ways, and rye straw is so much preferred to any other, that many of our farmers, especially in the East, raise rye more for the straw than for the grain.

IX. Barley, the Brewer's Grain.

Our study of wheat, oats, and rye has shown them to be examples of the general rule, that the characteristic food of a people is largely determined by the climate and soil of the region in which they live. The same rule applies to alcoholic beverages. Thus in southern Europe and other regions where the wine-grape grows well, wine is the common drink; and brandy, which is distilled from wine, is the form of spirit most in use. In such regions as northern Europe, however, which are too cool or too dry for wine-growing, the popular alcoholic drinks are obtained from grains. That is to say, whiskey and gin, which are distilled mostly from rye or maize, largely take the place of brandy; while beer, ale, and the like, which are made principally from barley, serve much the same purpose as wines. These facts add interest to the following statement of the ancient Grecian historian Herodotus regarding the Egyptians of his day: "They use," he says, "wine made of barley, for they have no [grape] vines in that country."[1] What Herodotus meant by "wine made of barley" was doubtless a sort of beer similar to what is brewed from barley to-day. At the present time, not only is beer made principally from barley, but the principal purpose for which barley is raised is the brewing of beer.

The process of brewing is essentially as follows: First, kernels of barley are soaked in water for a

[1] Herodotus, Book II., chapter 77.

while and then spread out to sprout. In the process of germination, as we have seen, the starch of the seed food is turned into sugar, which is then absorbed by the germ. Hence, up to a certain point in the process, the sugar increases in amount, and after that, becomes less and less as the plantlet grows. Just as soon as the brewer finds that the largest possible amount of sugar is present, the sprouting is stopped by heating the grains sufficiently to kill them. Grains thus sprouted and killed at the proper time are known as *malt.* Such was "the malt that lay in the house that Jack built." Malting is the first step in the making of beer. The second step is grinding the malt and soaking it in water to dissolve out the sugar. To the sweet liquid thus obtained yeast is added to bring about fermentation. As in the "raising" of bread, the sugar is transformed into alcohol and carbon dioxide gas. When the fermentation goes on in a closed vessel, as a cask or a bottle, the gas is retained in the liquid and when the beer is drawn forms bubbles of foam.

Just as sugar is turned to alcohol by yeast, so, through the action of another ferment, alcohol is turned to the acid of vinegar unless means are taken to prevent it. Beer is now generally kept from souring by the addition of hops, the flowers of which contain a bitter substance that does not interfere with the working of the yeast, but retards the action of the acid ferment.

Other malt liquors, such as ale and porter, are made from barley in much the same way as above described. When other grains are malted the process is the same as with barley. Spirituous liquors, such as whiskey and gin, are made by distilling a sort of

FIG. 25. Common bearded wheat, inflorescence. (Hackel.)

FIG. 26. Club wheat, inflorescence. (Hackel.)

beer. That is to say, from a weak alcoholic liquid — the fermented extract of some malted grain — a strong liquor is produced by a peculiar process of concentration.

Brewers prefer barley to any of the other grains for malting, because of its exceptionally ready germination. Its very general use for beer-making is favored also by the fact that it thrives over a wider range of climate than any other corn plant. It grows well even farther north than oats, and at the same time will flourish in sub-tropical soil.

The native home of barley is believed to be in southwestern Asia. (See map, p. 103.) From the very earliest times it has been extensively grown by the great peoples of antiquity who dwelt about the Mediterranean sea. Records of its use in ancient Egypt, Assyria, Palestine, and Greece, indicate that barley was cultivated as early as if not earlier than wheat.

Until modern times its principal use has been for food, although, as we have seen, it has long been used also for beer. As a bread-stuff barley has always ranked lower than wheat. It has served chiefly as a food for the poorer classes who could not afford much wheat. The ancients used to feed their athletes on barley bread, in the belief that it was an especially strengthening food. From their use of this food the Roman gladiators were called *hordearii*, or "barley-boys," as we may freely translate it, much as the name "beef-eaters" is now applied in England to the yeomen of the royal guard. In the great armies of antiquity barley was largely used as food for both man and beast. Nebuchadnezzar's horses and Solomon's dromedaries were doubtless fed on barley.

At the present day, in warm regions where oats do not thrive, barley is used considerably as a fodder. As a human food, however, it is now used only to a comparatively small extent throughout the world. With us it is eaten almost entirely as "pearl-barley." This consists of the kernels deprived of their outer coverings and rounded. It appears in modern cookery chiefly as an addition to broths or soups. The nutritive value of barley is usually less than that of either wheat, oats, or rye. From being the grain most used as food by the ancients, barley has now come to be eaten less than any other grain. Were it not for the extensive use made of this grain by brewers, only a comparatively insignificant amount would now be raised.

X. Rice, the Corn of the East.

Rice gives food to more people than any other corn plant. It is, however, the least nutritious of cereals, and as commonly cultivated would seem to require more labor and care than most of the other grains. Nevertheless, rice forms the chief food, and of the poorer classes almost the only food, throughout large parts of India,[1] China, Japan, and the East Indies. It is used also extensively in other regions of moist climate within or near the tropics. The main reason for its being the food of so large a part of the human race is doubtless to be sought in the fact that about half the population of the world live crowded together in the Eastern countries above named. There, owing to the heat and abundant moist-

[1] Indian millet takes the place of rice in the dry portions of India, and the total amount raised throughout the country is greater.

ure in the lowlands, rice yields more than any other cereal would do under the circumstances. Its native home (see map, p. 103) is in southeastern Asia. As we have already seen, rice has been cultivated by the people of the East for over forty centuries.

Growing rice affords some of the most attractive features of Eastern landscapes. The Rev. Francis Tiffany, writing of Japan, records as follows his impression of rice-fields :

"Not personally addicted to rice as an article of diet, — unless, perhaps, as a mere vehicle for the piquant stimulus of curry, — I was soon forced to admit that the cultivation of this cereal for purely æsthetic ends would prove an enhancement of the charms of the Garden of Eden. At this late September season of the year, the rice-lands stretch out in the sunshine a sea of gold. Since rice declines to grow except in water, and water declines to stand still except on a perfect level, the immense area of alluvial deposit in which the plant roots wears the look of a lake of luxuriant, sunlit vegetation. Encircling in graceful curves this vast burnished expanse — now jutting out into it in promontories and now retreating to leave space for lovely bays — are hills densely wooded, completing the picture with ravishing contrasts of form and color.

"Curiously enough, each charming little valley, with its brook winding down between the densely wooded hills to the shining level of the plain, now delights the eye with the exact transcript of a series of beautiful cascades of golden rice. As, in the gardens of Versailles, streams of water are made to run down great flights of broad stone steps, breaking into a gentle fall at each successive step, so here the same effect is wrought by utilizing the water of the descending brooks for successive terraces of rice. So vivid the impression of life and motion, that literally it seems as though the beautiful plant itself had taken to the mobile ways of the element in which it grows. When one pictures the scene of an infinite variety of these lovely little valleys pouring their brooks of gold through luxuriantly wooded defiles into a sea of gold below, he will have presented to the mind the sight that makes one of Japan's most characteristic beauties." [1]

In our country the cultivation of rice is restricted mostly to the low-lying parts of the South Atlantic and Gulf States. The total yield for the United States is less than that of any of the other cereals we have been considering.

XI. Maize, the Corn of the West.

Indian corn forms by far the largest cereal crop of the Western Hemisphere. In the United States the amount raised is greater than the sum of all our other grain crops, and doubtless considerably exceeds the total maize product of the rest of the world.

The place of maize in the Western Hemisphere is similar to that of rice in the far East. As the native home of rice was in tropical Asia so that of maize was in tropical America. (See map, p. 103.) Although in their original wild state both were thus tropical grasses, there was this important difference, that, whereas rice grew mainly in the wet lowlands,[2] maize

[1] *This Goodly Frame the Earth*, p. 27.

[2] Upland rice, a variety requiring about the same amount of moisture as maize, is cultivated to a limited extent on rather dry soils at considerable altitudes. It is much less productive

was a highland plant, and this fact has made possible a much greater range of cultivation for the corn of the West. That this would naturally be the case is plain when we remember that at high elevations in the tropics the climate is like that of lower altitudes in temperate lands, while the climate of tropical lowlands can be matched only within or near the tropical zone.

"Maize or 'Indian corn,'" says John Fiske,[1] "has played a most important part in the history of the New World, as regards both the red men and the white men. It could be planted without clearing or ploughing the soil. It was only necessary to girdle the trees with a stone hatchet, so as to destroy their leaves and let in the sunshine. A few scratches and digs were made in the ground with a stone digger, and the seed once dropped in took care of itself. The ears could hang for weeks after ripening, and could be picked off without meddling with the stalk; there was no need of threshing and winnowing. None of the Old World cereals can be cultivated without much more industry and intelligence. At the same time, when Indian corn is sown in tilled land it yields with little labor more than twice as much food per acre as any other kind of grain. This was of incalculable advantage to the English settlers in New England, who would have found it much harder to gain a secure foothold upon the soil if they had had to begin by preparing it for wheat and rye without the aid of the beautiful and beneficent American plant. The Indians of the Atlantic coast of North America for the most

than lowland rice, however, and the amount raised throughout the world is comparatively insignficant. The statements above apply only to lowland rice.

[1] *The Discovery of America*, vol. i. p. 27.

part lived in stockaded villages, and cultivated their corn along with beans, pumpkins, squashes, and tobacco; but their cultivation was of the rudest sort, and population was too sparse for much progress toward civilization. But Indian corn, when sown in carefully tilled and irrigated land, had much to do with the denser population, the increasing organization of labor, and the higher development in the arts, which characterized the confederacies of Mexico and Central America and all the pueblo Indians of the southwest."

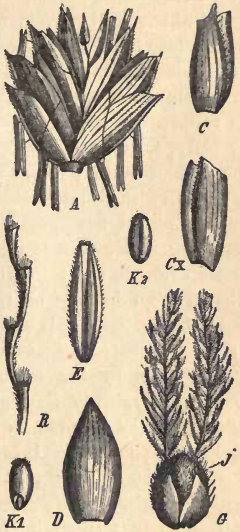

FIG. 27. Wheat. *A*, spikelet. *C*, *Cx*, outer bract, back and side views. *D*, *E*, inner bracts. *G*, pistil with pair of lodicules at base; *J*, ovary. K^1, K^2, kernel, front and back views. *R*, rachis. (Hackel.)

The religious ceremonies already referred to, in which the ancient Americans showed their appreciation of the value of maize, indicate plainly that these people must have been acquainted with the plant for many centuries before the coming of Columbus. Other facts go to show that long before his arrival the culture of maize had spread from Mexico as a centre into the temperate regions of North and South America.[1]

[1] The proofs of this view are given at length in Dr. John

When Columbus landed in the West Indies the natives gave him a sort of bread made from a grain which they called *mahiz.* In his letters to Spain he spoke of the Indian corn under this name, and from it has come our English word "maize."

Although Columbus and his followers on their return home took seeds of the Indian corn with them, its value seems to have been appreciated very slowly by Europeans outside of Spain and Portugal. Until the present century it was regarded by them rather as a curiosity than as a valuable food-plant. At the same time its use spread remarkably in Africa and Asia, extending even to China. "It is found at the present time in the East Indies among savage people, who have no history or tradition of how or when it was brought there. It appears to have been adopted by the barbarous nations of the Old World more rapidly than by the more enlightened countries of Europe. Probably this is due to the fact that it was peculiarly well adapted to the agriculture of a semi-barbarous people."[1] It is now cultivated very extensively in the warmer parts of the Old World, especially in Asia.

The early settlers in America learned from the natives, not only their simple method of raising the corn, but also some of the best ways of using it. In Mexico the Spaniards found the natives making a sort of bread after the following primitive fashion: They first soaked the whole kernels in hot water, with

W. Harshberger's *Maize: A Botanical and Economic Study,* 1893, which contains also much other valuable information regarding this plant.

[1] Wm. H. Brewer, Cereal Production, *Tenth Census of the United States,* iii. 475.

a little lime to soften the hulls, until the whole was tender; then the grains were cleaned and crushed, and finally made into a paste. This was baked by spreading a thin layer over heated stones. Such thin cakes, to which the Spaniards gave the name "tortillas," soon came to form the chief bread of the invaders, and to this day throughout Mexico it is a favorite food of all classes.

A somewhat similar food is prepared by the Indians of our southeastern States. It is thus described by one who has lived among them: "The blue variety [of corn] is preferred for bread, and is sorted from the rest with much care. . . . The corn, after being reduced to meal in a stone mortar, has a peculiar bluish-white appearance. In converting it into bread, it is mixed into a thin batter, and a brisk fire is made to heat a slab of iron or stone, or a flat earthenware plate; . . . when [the slab is] sufficiently heated the women press the fingers of the right hand together, dip them in the batter, draw them out thickly covered with the mixture, . . . [and pass] the hand equally over the heated baker, leaving a thin coating, which quickly curls up, a sign that it is cooked on that side; it is then taken off, another dip made with the fingers, and the baker is besmeared again; then the upper side of the first cake is laid on top of the new dip; when the second one is ready to turn, the first one is already cooked, and the second is put through the same process as the first; and so on until a number of these large thin sheets of wafer-like bread is accumulated. They are rolled up together and form what is called by the Moqui Indians 'guagava.' It looks like blue wrapping paper, but somewhat coarser and has a polished surface. . . . At first it seems dry in the mouth, but it soon softens, is quite sweet, and is easily masticated."[1] Other Indians make the meal into a flat cake which they cook in hot ashes. From such primitive examples of cookery were doubtless derived the "ash-cake," "hoe-cake," and "corn-pone," so widely relished throughout our Southern States.

The early settlers in New England adopted several of the Indian methods of preparing maize, and in some cases kept the native name for the dishes with but little change. Thus the mixture of green corn with beans, which is now known as "succotash," was called by the Indians *msickquatash.* Similarly our "hominy," which is a sort of maize "groats," was known to the Indians as *auhuminea.* Furthermore, we learn from Roger Williams,[2] the founder of Rhode Island, that the native *nasaump*, "a kind of meal pottage, unpartch'd," became the "samp" of the English colonists. "Samp," he says, "is the Indian corne, beaten and boiled, and eaten hot or cold with milke or butter, which are mercies beyond the native's plaine water, and is a dish exceeding wholesome for English bodies."

Parching or toasting the corn he further tells us was a method of preparation much practiced by the Indians. Regarding the parched meal, he writes: "[It] is a readie very wholesome food which they eat with a little water, hot or cold; I have travelled with neere 200. of them at once, neere 100. miles through the woods, every man carrying a *little Basket* of this at his back, and sometimes in a hollow girdle about his middle, sufficient for a man three or four daies;

[1] Food Products of the North American Indians, *Report U. S. Department of Agriculture,* 1870, p. 420.

[2] *A Key to the Languaye of America,* 1643, p. 12.

Fig. 28. Common barley. A, inflorescence. B, base of a single spikelet. (Hackel.)

Fig. 29. Two-rowed barley. A, inflorescence. B, base of a single spikelet. (Hackel.)

with this ready provision, and their Bow and Arrowes, are they ready for War, and travell at an *houres* warning. With a spoonfull of this meale and a spoonfull of water from the Brooke, have I made many a good dinner and supper." [1]

Dr. Benjamin Franklin tells us of the following curious method of parching corn practiced in his day by the farmers, and evidently borrowed from the Indians. "An iron pot is filled with sand, and set on the fire till the sand is very hot. Two or three pounds of the grain are then thrown in and well mixed with sand by stirring. Each grain bursts and throws out a white substance of twice its bigness. The sand is separated by a wire sieve, and returned into the pot to be again heated, and repeat the operation with fresh grain. That which is parched is pounded to a powder in mortars. This being sifted will keep long for use. A Indian will travel far and subsist long on a small bag of it, taking only six or eight ounces of it per day mixed with water." [2]

In this singular preparation, the reader will doubtless recognize the original of our modern "pop-corn," — a food as digestible as it is delicious, and one well worthy of wider use to-day.

Of the many other uses which maize has come to have in modern times, only brief reference may here be made to a few of the most important. Its value to man as furnishing a rich variety of food-products for himself is scarcely greater than its service in providing fodder for his domestic animals. The ripened grain affords a food which is exceptionally fattening, while the "stover," or those parts of the plant left

[1] The same, p. 10.

[2] *Franklin's Works,* 1818, vol. ii. p. 277.

after removal of the ears, is found to be as nutritious as the best hay. Farmers plant maize also very largely for green fodder. Either this is fed fresh or it is kept moist by packing closely in air-tight structures called "silos," where it ferments somewhat and becomes what is known as "ensilage."

The pith of the mature stalks yields a material which from its property of swelling rapidly when wet has an important use in the construction of war vessels. A thick layer of this material firmly packed behind the armor of the hull at and near the water line prevents leakage in case a shot penetrates the steel covering. Several of the battleships of the United States Navy are thus protected.

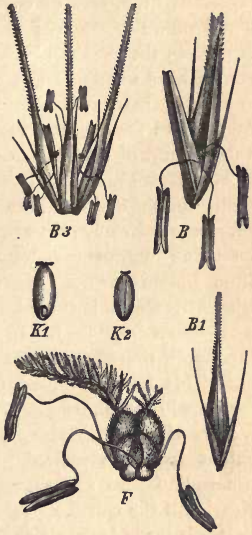

FIG. 30. Six-rowed barley. B^3, a group of three spikelets from one node of the rachis. B, B^1, single spikelets. F, a flower (one stigma partly removed). K^1, K^2, back and front views of kernel. (Nees.)

The stalks, leaves, and husks have been found to yield excellent material for paper, and also fibres which can be woven into fabrics. The husks have, moreover, considerable value as packing material, as stuffing for mattresses, as material for coarse matting, and other minor uses.

In the Western States, where coal and wood are especially high, ears of corn, or the cobs after shelling, form an economical fuel. One hundred bushels of corn in the ear are about equal in fuel value to a cord of hard wood ; three tons of corn-cobs equal about one ton of hard coal. In mills where corn-cobs are used to run the engines, the ashes furnish a considerable amount of potash.

The kernel of maize is so rich in starch that this grain forms our cheapest source of that important substance. Nearly all the starch used in this country, including "corn-starch" and laundry starch, is made from Indian corn. There are many large factories where the starch is turned into a kind of sugar much used by confectioners. In the process of separating the starch there is also obtained a certain amount of oil. This has been used for illuminating purposes, for dressing wool, as a machine oil, and in the manufacture of soap. Maize oil is extracted also to some extent from the malted grain in distilleries which use Indian corn as a source of whiskey and alcohol. Nearly all the spirit now manufactured in the United States is made from maize.

Finally, it must be said that maize has been used also in various ornamental ways. Its attractive foliage and graceful appearance have led horticulturists to plant it in gardens along with other ornamental grasses. They have, moreover, developed a special variety with striped leaves. Representations of the maize plant, as also of wheat, cotton, tobacco, and oak appear upon United States dimes, while ears of Indian corn, together with sprays of the cotton plant

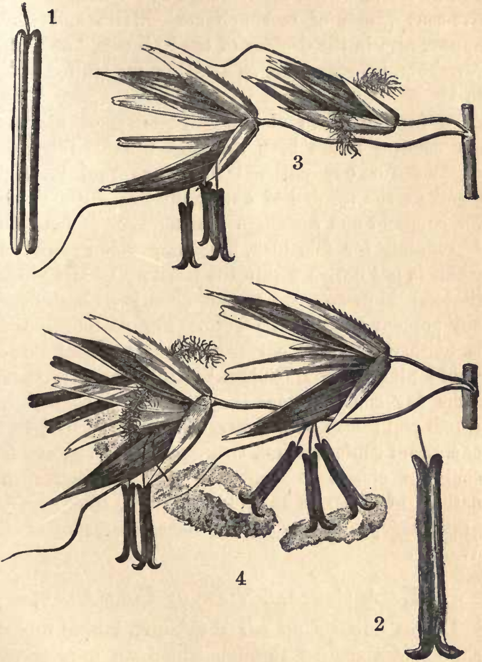

FIG. 31. Wild oat-grass. 1, a young anther. 2, a mature anther holding its pollen exposed. 3, two spikelets in still air; the left hand one with only stamens exposed, the other with only stigmas. 4, similar spikelets in a breeze, the left hand one having its pollen sacks empty before its stigmas are out, the other with only stamens exposed and these shedding their pollen freely in the wind. All enlarged. (Kerner.)

and heads of wheat, are included in the design of our five-cent pieces of recent issue. Maize and wheat appear also in the designs of the "Omaha" or Trans-Mississippi postage stamps issued by the United States in 1898.

In further token of the importance of maize to our country it has been proposed to have this plant adopted for our national flower, so that it might stand as the symbol of our country as does the rose for England and the chrysanthemum for Japan. Unfortunately for this idea, it is now well known that maize is not native within the territory of the United States. Moreover, we cannot class it as a *flower* in any popular sense of the word. For us to call what is neither a flower nor native our national flower, would plainly be ridiculous.[1] If, however, it should some day come to pass that the various countries of North and South and Central America shall join in one grand confederation, then surely no fitter emblem could be chosen to symbolize such a union of the nations of America than Indian corn, whose golden grain has proved to be the richest treasure of the West.

XII. A General View of Corn Plants.

Let us now tie up our sheaf, and, taking a broad survey of the field through which we have passed, let us try to gain a just idea of the place of corn plants in the world. Our study of the cereal grains has led us in imagination back to a time long before

[1] For a fuller discussion of the merits of this and other candidates for Columbia's floral emblem see *The National Flower Movement*, by the present writer, in the Proceedings of the Massachusetts Horticultural Society for 1898.

FIG. 32. Map of the world, showing the probable native homes of the various corn plants, according to recent authorities. (Original.)

the dawn of civilization, when our forefathers first gathered the grains of wild plants for their food. Since from seed-gathering, planting would easily follow, and from planting, agriculture; and since agriculture would favor the founding of mighty nations and so make possible the highest achievements of mankind, we may see that no act of these early ancestors of ours was more full of promise for the human race than their choice of grains as a food.

This choice was first made, it would seem, by men who came to the rich valley of two rivers which lay at the centre of the ancient world. Also in moist, hot lowlands of the far East, and on a fertile highland between the two great Western continents, a similar choice was made by other races of men perhaps ages after; while later still, it may be, ruder northern tribes in cooler and drier regions came to use the wild grains which grew near their hunting grounds.

However this choice came about, we may say that in favored spots of North and West and East and Midland, man found awaiting him, among the many plants that sprang luxuriantly from the soil, certain grasses which outdid all the rest in the abundance and quality of the food they offered him. These grasses were born to a life in the open fields where they could best obtain plenty of food-making sunshine; there they grew as if they had learned to outwit the wind and undo the harm of the pelting rain to which they were exposed; and when drought came it found them well prepared. Moreover, they made the utmost use of every inch of ground, and formed vast brotherhoods which crowded out less sturdy or less enterprising plants. But best of all were the advantages these plants secured for their offspring.

The seeds were so formed that the infant plant inherited the utmost vigor from its parents. Protection against various enemies was provided from the first. As soon as it was ripe, special arrangements were ready for its safe carriage by the wind to some favorable place of growth. Finally, against the time when the little traveler should begin life in a new home, an abundant supply of most nutritious food was packed within easy reach. This food was of sorts best fitted for transportation and keeping, and means were provided for readily converting it from the solid to the liquid form whenever needed. Everything was done to give the plantlet a good start in life.

It was but natural that plants which accomplished so much for themselves and provided so well for their offspring should be chosen by man to supply his needs. Nor should we be surprised that they have proved to be the best of his providers.

He has repaid their bounty by his care. As they have fed him, he has enriched the soil in which they grew; as they have helped him to travel, he has carried them to fresh fields in distant lands; as they have served him in war, he has fought against their enemies; as through their wealth man has multiplied, and great nations have peopled the earth, he has established these plants in ever increasing numbers throughout the world. Wild grasses and savages have thus through mutual help developed into cultivated cereals and civilized men.

During the long companionship of these two classes of beings, so different in their ways of life, and yet with needs so much alike, man has felt that he and they were somehow made to be of service one to the other. He has seen this doubly helpful dependence to be part of the wise plan of the Maker of all for the best good of each. As richer and richer harvests have yielded their reward for man's toil, he has felt an ever deepening thankfulness to the Giver of Life. Now, with new hope of the highest gifts, he asks his Father, "Give us this day our daily bread."

Tout bien ou rien
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